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A
TREATISE
ON THE
VARIOUS KINDS
OF
PERMANENTLY ELASTIC FLUIDS,
OR
GASES.

The SECOND EDITION, *reviſed.*

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BRITISH MUSEUM
10 AUG 34

To

The Rev^{d} JOSEPH PRIESTLEY, LL.D. F.R.S.

The following *Treatiſe* on permanently elaſtic Fluids

Is Inſcribed

By the *Author*;

As a ſmall Tribute juſtly due to the *Philoſopher*,

Who, by the *Zeal*, *Sagacity*, and *Succeſs*,

With which he conducted his *Experiments* on theſe Fluids,

Has opened

Many New and Rich Sources of Knowledge

in

Natural Philoſophy.

PREFACE.

THE following ſheets are intended as an *Appendix* to the ſecond Engliſh Edition of M. *Macquer's Dictionary of Chemiſtry*, inſtead of the article *Fixable Air*, which was added to the former edition. This ſubject has been lately ſo ſucceſsfully cultivated, ſince the writing of that article, that a reviſal and large additions were neceſſary: but theſe not having been finiſhed in time for inſertion into their proper alphabetical place, when the ſecond edition of the Dictionary was printing, and being beſides too large for an additional article, the following Treatiſe is ſubjoined as an Appendix to that work.

The name of the ſubject is changed from thoſe commonly employed by Engliſh authors, viz. *Fixable*, *Fixed*, or *Factitious Air*, to that of *Gas*; a word applied to diſtinguiſh permanently elaſtic fluids by *Van Helmont*, who firſt diſcovered, or, at leaſt, deſcribed more clearly than his predeceſſors, many kinds of theſe fluids. The impropriety of applying the word *Air* to all permanently elaſtic fluids is evident, from conſidering that this word has been immemorially appropriated to expreſs only one of theſe, namely, the atmoſpherical fluid, and that the other elaſtic fluids are very different in moſt of their properties, although they have been frequently confounded with it. The impropriety would not be greater, if all *liquids* were confounded under the name of *Water*. And probably the firſt diſcoverer of other liquids committed this impropriety. Oil he might call inflammable water; and vinegar, acid water.

The application of the word *Air* in a *generical* ſenſe to expreſs all permanently elaſtic fluids, inſtead of confining it to its ancient ſpecific meaning, denoting the atmoſpherical fluid, was introduced by *Boyle*, in conſequence of an erroneous opinion which he entertained, that all theſe fluids are modifications of the atmoſpherical fluid. This phraſeology, founded on error, has nevertheleſs been continued by the reſpectable philoſophers who have ſucceeded that author; although they were ſufficiently ſenſible of the difference between the atmoſpherical and the other permanently elaſtic fluids. Intent only on the communication of their own very important diſcoveries, they continued the language of *Boyle*, and extended it to the new fluids which occurred to them in their reſearches. Thus Dr. *Prieſtley*, in his late moſt ſucceſsful proſecution of this ſubject, having obſerved not only many new properties of the fluids formerly known, but alſo diſcovered ſeveral new fluids, and finding that the word *Air* had been applied by his Engliſh predeceſſors to denote generally all permanently elaſtic fluids, has, in conformity with a language which appeared to be in ſome meaſure eſtabliſhed, given to his newly-diſcovered fluids, the appellations of *vitriolic acid air*, *marine acid air*, *fluor acid air*, *nitrous air*, &c. And in continuing the ſame mode of appellation, he certainly conſulted the eaſe of his readers, who were ſuppoſed to be converſant with the writings of his predeceſſors, and to whom he meant chiefly to communicate the further progreſs he had made in this ſubject.

But the circumſtances under which the following Treatiſe is written, are ſo different from thoſe of the celebrated authors who have ſo happily cultivated this ſubject, that the ſame reaſons which may be alledged to ſhew the propriety of their continuance of the language of *Boyle* are not here applicable: for this ſubject has received ſo very rapid an advancement within theſe few years, that it has riſen from a few ſcattered facts, to be now one of the moſt important branches of Natural Philoſophy; and this change is ſo recent, that no attempt has before been made to arrange theſe facts, and to give them the form and method of a ſcience. As I have firſt undertaken that taſk, it appeared not uſeleſs to reviſe the expreſſions hitherto employed; and as a *ſyſtematic* treatiſe, like the following, is chiefly intended for perſons beginning to ſtudy the ſubject, I thought that it ought to adopt that phraſeology which appeared to be the moſt perſpicuous, and leaſt capable of miſleading the judgment. But certainly the language which is entitled to this deſcription, is that in which known and eſtabliſhed words are applied and confined to their known and eſtabliſhed meanings, and new words are appropriated to expreſs new ideas. Now the word *Air* having been immemorially aſſigned to denote the fluid which we breathe, which is one ſpecies only of permanently elaſtic fluids, cannot be applied in a generic ſenſe to the other ſpecies of theſe fluids, without giving the idea of *Boyle*, that they are all modifications of that reſpirable fluid. And accordingly I have always perceived that perſons not converſant in the ſubject received this impreſſion from the names *Fixed Air*, *Factitious Air*, &c.

If it be alledged, that as *Boyle*, *Hales*, and all the Engliſh philoſophers who have written on the ſubject, have uſed the word *Air* in a generic ſenſe, they have thereby eſtabliſhed the cuſtom. I grant that *cuſtom* is the arbiter of language; but as in law, ſo in language, cuſtoms may be good or bad, according to their extent. Now the cuſtom by which *air* has been uſed in a generic ſenſe, is confined chiefly to a few Engliſh philoſophers: but the cuſtom on which the ſpecific meaning of that word reſts, is popular, and ſo fixed in language, that the combined authority of all the philoſophers in the world could not induce mankind (when they mean to expreſs the well-known fluid which they breathe) to uſe the epithets *common*, *reſpirable*, or *atmoſpherical*, by which that fluid muſt be diſtinguiſhed by all thoſe who employ the word *Air* in a generic ſenſe. While therefore that word is ſo employed, the philoſophical language will be at variance with the popular language, and the acquiſition of ſcience be thereby obſtructed.

When *Van Helmont* obſerved that there were many fluids, beſides air, which were poſſeſſed of a permanent elaſticity, and that the properties of theſe fluids were different from thoſe of air, he very properly gave one name to the whole genus of ſuch fluids, and diſtinguiſhed the ſeveral ſpecies by deſcriptive epithets added to the common generical name. And as he ſeems to have been the firſt who had the idea of a genus of permanently elaſtic fluids, (his predeceſſors conſidering all but air as condenſable vapours) he accordingly applied a new word to ſignify this new idea. And in this conduct, he followed the example of all thoſe who have arranged natural ſubſtances into genera and ſpecies. The word which he applied to denote the genus of permanently elaſtic fluids, is *Gas*, and the epithets which he added to this word to diſtinguiſh the different ſpecies, are, *ſylveſtre*, *flammeum*, *ventoſum*, &c. According to *Junker*, (Conſpectus Chemiæ, Tabul. XIV.) *Van Helmont* derived the word Gas from the German *Gaſcht*, or *Gaſt*, which ſignifies a frothy ebullition or eruption of wind, ſuch as accompanies the expulſion of gas from fermenting or effervefcing ſubſtances. In this reſpect the etymology is not exceptionable; but perhaps the principal advantage of the word is, that its etymology is ſo far from being obvious, that it cannot lead to any erroneous opinions.

In this application of the word *Gas*, *Van Helmont* has been followed by many of the foreign chemiſts, and among others, by M. *Mac-*

Macquer, the author of the Dictionary of Chemiſtry. But as this Treatiſe is intended principally as an Appendix to the Engliſh tranſlation of that work, the ſame language ought to prevail in both, and this conſideration too was an additional reaſon to induce me to adopt the preſent phraſeology.

It has indeed been lately ſuggeſted that *Van Helmont* did not diſtinguiſh permanently elaſtic fluids from condenſable vapours and exhalations. But I think a very different opinion will be formed on examining his works, in which the following obſervations, among many others on this ſubject, are found.

1. Certain fluids (to which he firſt gave the name of *Gas)* eſcape from various ſubſtances and in various proceſſes. Among the many Gaſes mentioned by *Van Helmont* are, the *gas ventoſum*, or air; the *gas pingue*, or the fluid extricated by applying heat to inflammable ſubſtances; the *gas ſylveſtre*, or the fluid produced by fermenting or efferveſcing ſubſtances; the *gas flammeum*, or the gas produced in the deflagration of *nitre*; the *gas* produced in the diſtillation of *tartar*; the *gas* produced in the burning of *charcoal*; the *gas* of the *Grotta del Cane*, of *mines*, and other *ſubterranean places*; the *gas* produced by the *putrefaction* of animal

bodies; the matter which occaſions the *plague*; the *arterial ſpirit of life*; and laſtly, his celebrated *Archæus*.

2. Theſe Gaſes *differ from vapour*, which conſiſts of minute particles of water or other liquids, and which may be again reduced to the ſame bodies whence it was exhaled; whereas gaſes are incondenſable [*quod in corpus non cogi poteſt viſibile*; and *incoagulabile*.] *De flatibus* §. 33. *Paradox. ſecund.* §. 9. *Aura vitalis**. Thus he obſerves, that the vapour raiſed from ſpirit of nitre by diſtillation, is nothing but that ſpirit rarefied, which paſſes wholly into the receiver, without any gas: but that upon adding any metal ſoluble in that acid, a gas is formed, which is capable of burſting the ſtrongeſt veſſels. *De flatibus* §. 67. This gas is evidently that which is now ſo well known by the name of *Nitrous Air*, and which we have deſcribed in chap. X. under the name of *Nitrous Gas*.

3. The Gaſes *differ alſo from atmoſpherical air*, (which however he calls ſometimes *gas ventoſum*)

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* He ſays indeed that the vapour of water when raiſed into the upper regions of the air may, by cold, be converted into gas; and that gas may, in length of time, loſe its peculiar nature of gas and be converted into water. But this opinion is only a conſequence of his general theory, that water and air are the two elements from which all things are formed. *Gas aquæ* §. 13. *Complex. atq. Miſtion. elem. figm.* §. 38,

ſum) and are not to be conſidered as air which had been pent up in the interſtices of bodies. *Complexion. atq. Miſtion. elem. figm.* §. 19.

4. Gaſes do not exiſt, as ſuch, in the bodies, whence they are expelled, but are *new productions* formed, by the action of fermentation, fire, and other cauſes, from the deſtruction of bodies, and by means of new combinations. Thus he obſerves, that the gas formed in the deflagration of gun-powder, did not exiſt in the nitre, ſulphur, and charcoal, but is formed by their action on each other, and mutual deſtruction. *De flatib.* §. 62, 63. 67, 68. *Complexion. atq. Miſtion. elem. figm.* §. 21, &c.

It muſt however be confeſſed, that *Van Helmont*'s knowledge of theſe fluids does not ſeem to have had much foundation in experiment, or any other ſupport than the caſual obſervation of an ingenious man, more intent on framing theories than eſtabliſhing new facts. For when his doctrines became exploded, the facts he mentions were ſo neglected, that notwithſtanding the exiſtence of ſo many gaſes is aſſerted by him, I do not believe that his writings ſuggeſted the idea of any one of them to thoſe who afterwards diſcovered them: and it is now only, ſince their exiſtence has been again diſcovered and aſcertained, that we trace them in the works of this author, as a matter of curioſity. While therefore we applaud the ſagacity of *Van Helmont*, in having obſerved the exiſtence of many permanently elaſtic fluids, and in diſtinguiſhing them from condenſable vapours, and alſo from air; we ought not in juſtice to make any abatement from the honour due to *Boyle* and his ſucceſſors who afterwards diſcovered the exiſtence and properties of theſe fluids, collected them in ſeparate veſſels, ſubjected them to various modes of experiment, and thence made applications to explain the phenomena of nature. I have therefore omitted making any further mention of *Van Helmont* in the following chapters, having here collected into one view the ſum of what I think is due to him.

I believe the following Treatiſe is the firſt attempt to arrange the knowledge which we have acquired on this ſubject, the gentlemen to whom we are obliged for this knowledge, having only communicated their proper diſcoveries. Neither ſhould I, at this time, when this branch of Experimental Philoſophy is generally cultivated in many parts of *Europe*, and every day brings forth new truths, have thought of the preſent taſk, if it had not been a neceſſary ſupplement to the edition of the Dictionary of Chemiſtry now publiſhed. M. *Lavoiſier* has indeed given an account of the progreſs made by the ſeveral philoſophers who have advanced our knowledge on the ſame ſubject. But his plan is very different from mine. He relates the diſcoveries in the order in which they occurred to their authors ; thus including in one chapter all the diſcoveries made by one man concerning many different kinds of fluids. I relate theſe diſcoveries in the order in which they are naturally connected ; thus collecting into one chapter all that is known concerning one fluid ; and at the ſame time aſſigning each diſcovery, concerning this fluid, to its proper author. M. *Lavoiſier*'s work is uſeful and entertaining, eſpecially to thoſe who are already converſant on the ſubject, as it ſhews how much each perſon has contributed. Mine I hope will not be leſs uſeful, as it preſents the ſcience in the order in which it is naturally connected, and in which it may be moſt eaſily attained. But while I expreſs my hope that this Treatiſe may facilitate the ſtudy of the ſubject to learners, and may even be agreeable to perſons already informed, by exhibiting under one view the principal diſcoveries and obſervations arranged under their proper heads, yet my aim is not to *ſatisfy* the curioſity of readers, but rather to *excite* it, ſo that they may recur to the ſame valuable originals, of which I have rather extracted the heads, than exhauſted the contents; and where they will find many obſervations tending to confirm the principal reſults; many facts curious, but too detached for inſertion in the following pages; and much ingenious ſpeculation.

ERRATA.

Page 21. *Note.* Line 12. Inſtead of—"a green matter which "adheres to the ſides of veſſels filled with water, does, in a few "hours after it is put under an inverted jar full of water, emit "a conſiderable quantity of *pure* air," read—"the water which "has depoſited a green matter, that uſually adheres to the ſides "of veſſels filled with water, being put into an inverted jar, "emits a conſiderable quantity of pure air."

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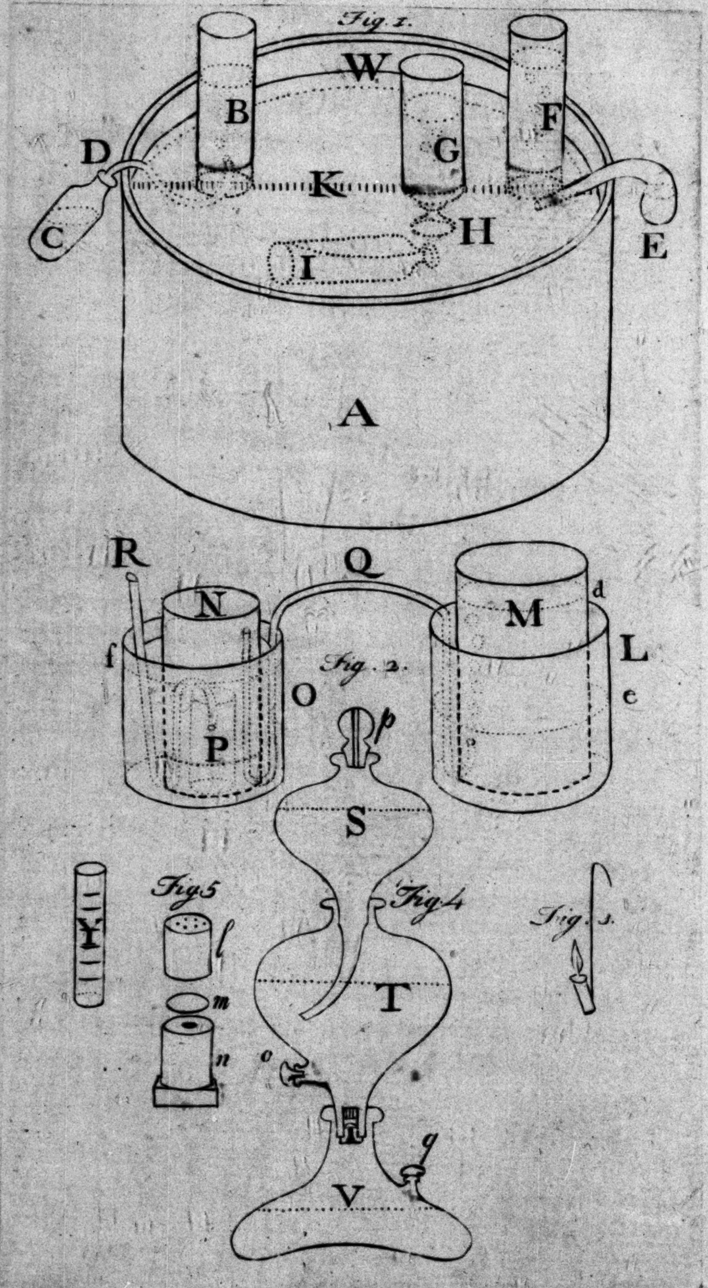
Fig. 1.
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Fig. 2.
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Fig. 5
Fig. 4
Fig. 3.
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V

Explanation of the PLATE.

TO ſhew the method of making experiments on the elaſtic fluids or gaſes deſcribed in this Treatiſe, the annexed plate and the following explanation are added.

The gaſes ought to be contained in jars, or other glaſs veſſels, B, G, F, (*Fig.* 1.) whoſe mouths are inverted into water or ſome other viſible fluid, that the gaſes may be kept ſeparate from the atmoſpherical air, and that their bulk may be diſtinguiſhed.

When a jar, as B, is intended to receive any gas, it ought to be previouſly filled with water, and its mouth inverted into another larger veſſel, containing alſo water, ſuch as the oval or oblong wooden tub A, which ought to be raiſed ſo that it may be as high as the operator's hands. This tub, being filled with water up to W, is a very convenient veſſel for receiving ſuch inverted jars; as it affords room for ſeveral of them to ſtand in it at once; and thus the gaſes contained in them may be poured from one jar into another jar, or other inverted bottle G. If the mouth of the bottle G be narrow, the transfuſion of gas into it from another veſſel I, is facilitated by the funnel H. This method of pouring gaſes from one veſſel into another, by immerſing the mouths of the veſſels under water, is deſcribed by the Hon. Mr. *Cavendiſh*, Phil. Tranſ. 1766.

In the tub A, Dr. *Prieſtley* places a ſhelf K a little below the ſurface of the water, for the more commodious ſupport of jars containing the different kinds of gas. The jar B, which is to receive the gas, ought to be placed ſo upon the ſhelf, that one of the edges of its mouth ſhall hang over the ſhelf, and that the mouth of the glaſs tube D may be allowed to paſs under that edge; by which diſpoſition the gas iſſuing from the phial C through the tube D may riſe into the jar B. Some perſons recommend to have the ſhelf pierced with a row of holes along its edge, and to have a ſmall funnel with its mouth inverted fixed into each of theſe holes.

In order to procure gas, let the materials, which are to yield it, be put into a phial C, into the neck of which is ground a bent glaſs tube D: or, the tube may be made to paſs through a cork fitted into the mouth of the phial, in thoſe operations where the materials employed are not capable of corroding the cork, and thereby of altering the quality of the gas. Let the end of the bent tube which is moſt remote from the phial, be ſunk in the water of the tub A, ſo that it ſhall be immediately under the mouth of an inverted jar B previouſly filled with water, and that the gas produced from the materials in the phial ſhall paſs through the tube into the jar, in which it will diſplace part of the water, and be collected. If heat be required for the production of the gas, the flame of a candle or of a lamp may be applied to the bottom of the phial, which ought to be blown thin and round, that it may be leſs liable to crack by the heat. The above method of procuring gas is employed and deſcribed by Dr. *Prieſtley*, in his *Obſervations and Experiments upon Air*.

This operation may alſo be very well performed, by employing, inſtead of the phial and tube, a ſmall retort E, with a long narrow neck, the mouth of which is immerſed in water under the mouth of an inverted jar F. Such ſmall retorts are very convenient, as they have no joints; and where conſiderable heat is to be applied, a chafing-diſh with lighted charcoal may be put under their bottoms.

When a heat greater than glaſs veſſels can ſuſtain is to be applied, the materials are to be put into a gun-barrel, or other metallic tube, and the cloſe end of the barrel, in which the materials lie, may be put between the bars of a common grate, among the burning coals, and to the mouth of the barrel may be fitted, by means of lute, a glaſs tube, the noſe of which may be placed under the mouth of an inverted jar previouſly filled with water, and ſtanding in the tub, into which jar the gas expelled by the violent heat from the materials in the gun-barrel will paſs and be collected.

As ſome gaſes are capable of being abſorbed by water, ſuch as the *acid* and *alkaline* gaſes, this liquid is not fit to be employed to contain them, &c. therefore quickſilver muſt be ſubſtituted. For this purpoſe Dr. *Prieſtley* recommends the uſe of a ſmall wooden trough to contain the quickſilver, in which the ſame operations with ſmaller jars may be performed, as are above deſcribed to be done in the wooden tub, *Fig.* 1.

When a jar containing gas is to be removed from the tub, let a hollow plate, ſaucer, or other veſſel, whoſe orifice is wider than that of the jar, be immerſed in the tub, and ſlipped under the inverted mouth of the jar. The two veſſels may then be removed from the tub, and the external air will be prevented by the water contained in the lower veſſel from entering the jar and mixing with the contained gas. By this method any number of jars containing gas of different kinds may be ſet apart, for future experiments, and when there is occaſion to pour any of the gas contained in them into other veſſels, they muſt be again immerſed in the tub, and the transfuſion performed as before directed. When, in making experiments upon theſe fluids, jars containing gaſes of different kinds are ſet apart, it is neceſſary to ticket them, in order to prevent miſtakes.

When a quantity of gas is to be tranſported to a diſtant place, a bottle may be filled with it by means of a funnel in the manner repreſented in *Fig.* 1. G, H; and a cork may be introduced under water into the neck of the bottle. The gas thus contained in the bottle, and ſecluded from the external air by means of the cork and the ſmall quantity of water that remains in the neck of the bottle, with which the cork is kept moiſt, may be carried ſafely to any diſtance, if care be taken to keep it in an inverted poſition.

That the gas may be mixed with as little air, as is poſſible, it is proper to allow the efferveſcence of the materials to proceed during a minute or two before the mouth of the tube or of the retort be put under the inverted jar. By this method the greateſt part of the air contained in the veſſels is thrown out; although ſome ſmall portion will always remain. If the gas ſhould be required perfectly free from air, the following apparatus may be employed.

Into two glaſs jars L and O (*Fig.* 2.) let two ſmaller jars M and N be inverted; and let a communication be formed between the two inverted jars, by means of a bent tube Q, each extremity of which opens into one of theſe jars. Under the inverted jar N, let a ſmaller veſſel P be placed to contain the efferveſcing materials. The air contained in the ſeveral jars and tube is to be expelled, by plunging them into the water of the tub A, and joining them while immerſed and full of water, in the order repreſented in the plate. The apparatus thus joined, and full of water, may be removed from the tub, and ſet upon a table. To prevent the water contained in the jars from running over during the efferveſcence, part of it ought to be drawn off from the jars L and O, by putting the ſhorter leg of a ſyphon or bent tube, previouſly filled with water, into either of theſe veſſels, till the ſurface of the water in the outer jars be lowered to about the height of the dotted line *e*. The apparatus being thus prepared, if the matter, from which the gas is to be procured, be a liquid, as the ſolution of potaſh in water, it may be poured through the tube R into the veſſel P; and an acid may be afterwards poured through another ſimilar tube into the ſame veſſel, where the acid and alkaline liquors mixing with the water contained in the veſſel, and with each other, produce an efferveſcence. The gas riſes towards the top of the inverted jar N, and puſhes the water into the jar O. As more gas riſes, it occupies more and more of the ſpace of the jar N, and it gradually forces its way through the bent tube Q into the jar M, where it is collected. For, its paſſage through the tube Q into the jar M, is reſiſted only by the column of water contained in the jar L, that is, from the ſurface of the water at *e*, to the bottom of the jar L; whereas the eſcape of the gas under the inverted mouth of the jar N, is reſiſted by the column of water in the jar O, the height of which is meaſured by the diſtance between *f*, repreſenting the ſurface of the water, and the bottom of the jar. And this column is rendered higher than the former column; becauſe a part of the water of the jar N is forced out of it into the jar O, by the gas occupying the upper part of N. But when the gas paſſes into the jar M, it forces part of the contained water into the jar L, and may raiſe the column of water there ſo high, that the gas ſhall eſcape under the inverted mouth of the jar N into the open air, more eaſily, than it can paſs through the tube Q into the jar M. It is therefore neceſſary, during the operation, ſometimes to draw off part of the water from the jar L, by means of a ſyphon, that the paſſage of the gas into the jar M may be facilitated. When the jar M is nearly full of gas, it may be raiſed a little, in order to diſengage it from the end of the tube Q, and may be then removed along with the jar L; and two other ſimilar jars, one inverted within the other, and both previouſly filled with water, may be ſubſtituted in the place of L and M, to receive the gas which continues to paſs through the tube Q. The operation may be continued by changing the jars, and by adding occaſionally more alkaline or acid liquor through the tube R; and large quantities of gas obtained without any mixture of external air.

If the ſubſtance, from which the gas is to be produced, be ſolid, as marble, or metals, it may be put into the veſſels P, before the apparatus is removed from the tub of water, and the acid liquor may be poured upon it through the tube R, as above deſcribed.

If conſiderable heat be required to produce gas perfectly free from mixture of external air, the moſt accurate method of accompliſhing this purpoſe is that practiſed by Dr. *Prieſtley* in ſome of his experiments, namely, to put the ſubſtance, whence the gas is to be produced, into a phial, the bottom of which is thin and round; to fill up the phial with mercury; to invert this phial into a baſon containing mercury; and to throw the focus of a concave mirror, or of a lens, upon the ſubſtance, which being lighter than the mercury, will float on the ſurface of this fluid, under the thin bottom of the inverted phial.

To try the effect of any gas upon the flame of a candle, let a piece of wax taper be faſtened to one end of a wire, as is repreſented in *Fig.* 3. and let the lighted taper be dipt into a ſmall jar Y, previouſly filled with the gas or air to be tried.

When the diminution occaſioned by mixing nitrous gas with air is to be obſerved, it will be proper to have two or more ſmall jars Y, graduated with a file or diamond, each degree being equal in contents to an ounce meaſure of water, or to any other given bulk. By means of theſe graduated jars, the quantities intended to be mixed of the air and nitrous gas may be firſt meaſured ſeparately, and the diminution, which they ſuffer by their action on each other, may be collected from obſerving the ſpace occupied by them, after they have been mixed.

Signor *Landriani*, Abbe *Fontana*, and Mr. *Magellan*, have each invented inſtruments, which they call *eudiometers*, by which the diminution upon mixing air with nitrous gas, and conſequently the degree of ſalubrity of the air examined, are intended to be aſcertained more commodiouſly, eſpecially upon journeys, than by the abovementioned apparatus of graduated jars. But notwithſtanding the ingenuity ſhewn in the contrivance of theſe inſtruments, the greater ſimplicity of the graduated jars will, perhaps, claim the preference. For although this apparatus requires a pretty large veſſel of water, in which the transfuſion of the air and gas is to be performed, and although it is therefore not ſo portable as the *eudiometers*, yet no inconveniency will ariſe, when we conſider the facility of tranſporting the air to be tried. For which purpoſe, nothing more is required than to carry a phial filled with water to the place, the air of which is to be examined, and to empty the phial in this place; by which means it will become filled with the air required, and by corking the phial, the air will be prevented from mixing with any other air, and may be kept till a convenient opportunity offers for trying its purity, by mixing it with nitrous gas in a graduated jar, as is above deſcribed.

Fig. 4. repreſents a ſection of an apparatus of glaſs veſſels, in which water may be impregnated with the gas extricated from chalk and other calcareous or alkaline ſubſtances, by means of acids. *See chap. XIV. of this Treatiſe*, §. 118. This apparatus, which was invented by Dr. *Nooth*, and is deſcribed in the *Phil. Tranſ. vol. 65th*, conſiſts of three veſſels, S, T, and V, well fitted, by grinding, into each other, in the manner repreſented in the plate; and of a glaſs valve placed in the lower neck of the veſſel T, ſo contrived, that it ſhall admit the gas, which is extricated from the effervesſcing materials contained in the veſſel V, to paſs from this veſſel into the veſſel T containing the water to be impregnated; but that it ſhall prevent this water from falling into the veſſel V. This valve conſiſts of three pieces, views of which are repreſented upon a larger ſcale by the figures *l*, *m* and *n*. The pieces *l* and *n* are cylinders fitted by grinding into the lower neck of the veſſel T. The lower piece *n* is perforated along the axis of the cylinder. In the upper piece *l*, there are ſeveral very ſmall perforations parallel to its axis. Between theſe two perforated cylinders is placed the piece *m*, which is a ſegment of a ſphere, and is moveable. The level ſurface of this ſegment reſts upon the upper, ſmooth, and level ſurface of the piece *n*, covering the perforation, and thereby preventing the water contained in the veſſel T from falling into the veſſel V.

When the apparatus is to be uſed, let the upper veſſel S be diſengaged, and the veſſel T be filled with the water to be impregnated. Let as much water be poured into the lower veſſel V as is ſufficient to cover the bottom of the veſſel. Some powdered chalk is to be thrown into this veſſel; and then, as much acid of vitriol, as may be thought ſufficient to ſaturate the chalk, is to be added. Theſe effervеſcing materials may be put into the veſſel V, either through the mouth of this veſſel, after the veſſel T has been diſengaged from it; or, without diſengaging the veſſel T, through the aperture *q*, which is afterwards to be accurately cloſed with a ground ſtopper. Laſtly, the veſſel S is to be fitted to the veſſel T. When the gas riſes from the effervеſcing materials contained in the veſſel V, it paſſes through the perforation of the cylinder *n*; preſſes upon the level ſurface of the lenticular piece *m*; raiſes this piece a little upwards; eſcapes into the ſmall ſpace between the two cylinders *l* and *n*; and thence aſcends through the ſmall perforations of the cylinder *l*, and alſo through the water contained in the veſſel T, in the upper part of which it remains collected. When the gas enters the veſſel T, it forces ſome of the water, contained in this veſſel, to riſe into the upper veſſel S, which is left open, or is only cloſed with a perforated ſtopper, that vent may be given to the contained air, when the water is thus forced into this upper veſſel.

The gas remaining in the upper part of the veſſel T is gradually abſorbed by the water contained in this veſſel; and this abſorption may be promoted by frequent agitation, which brings new portions of the water into contact with the gas. The abſorption of gas is alſo promoted by the preſſure occaſioned by the column of water raiſed up into the veſſel S. For preſſure facilitates the abſorption, as Mr. *Cavendiſh* has obſerved. The preſſure might be increaſed to any given degree, by a valve (ſimilar to the ſafety-valve of a fire-engine) fitted into the mouth of the veſſel S; or by a mercurial gage, as has been propoſed by Mr. *Warltire*, (*Exper. and Obſerv. vol. III. Append.*) And thus a much ſtronger impregnation of water with gas may be effected, than is poſſible without artificial compreſſion. Cold alſo facilitates the abſorption, as appears from the experiments of Dr. *Hales*. For the more commodious agitation of the water, Mr. *Magellan* has added to the above deſcribed apparatus two more veſſels ſimilar to S and T, by means of which the impregnation of water may be carried on at once in two ſets of veſſels, one of which ſets is to be agitated, while the other is receiving the gas from the effervеſcing mixture in the lower veſſel V, and thus the water in each ſet of veſſels is alternately ſupplied with gas and agitated. By this method water may be impregnated with gas in a few minutes.

As the veſſel V contains much air, at the beginning of the operation, it is proper to let the effervеſcence proceed, during ſome minutes, before the ſeveral veſſels of the apparatus are joined together, that the greateſt part of the air may be expelled, before any gas is collected in the veſſel T. When the water is ſufficiently impregnated, it may be occaſionally drawn off at the ſpout *o*, by removing the ſtopper.

To the water thus impregnated with gas ingredients may be added to give to it the peculiar qualities of the ſeveral mineral waters. Thus by adding a piece of iron to the impregnated water, the chalybeate property of *Pyrmont* water may be communicated.

Dr. *Prieſtley* impregnated water, by expoſing it to the ſtratum of gas which floats over the ſurface of liquors undergoing the vinous fermentation in a brewery, and by pouring this water from one veſſel to another, in order to encreaſe its ſurface, and thereby to haſten the impregnation. The *Duke de Chaulnes* has ſhewn how very large quantities of water may be impregnated very expeditiouſly with the gas of a brewery, by agitating the water immerſed in the ſtratum of gas. The agitation is performed by means of an inſtrument compoſed of many pieces of wood paſſing tranſverſely through a long axis, and ſimilar to the inſtrument uſed for frothing chocolate. This inſtrument being put into a tub filled with water to be impregnated, is to be turned quickly and alternately from right to left, and from left to right, and thus a ſtrong impregnation is ſaid to be given in a few minutes. The Duke recommends that conſiderable quantities of water ſhould be thus impregnated in great breweries, and put into large bottles well corked and waxed, in which it may be ſafely tranſported, and kept till it is uſed *.

Many

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* The *Duke de Chaulnes* availed himſelf of the great quantities of this gas which is to be found in a brewery to exhibit, in preſence of the Academy of Sciences, ſeveral of its properties more at large than had been done before, at leaſt in *France*, where the ſubject is much more recently cultivated than in *England*, and he accompanied his experiments with a memoir on the phenomena produced by this gas, which will be printed in the next volume of *Memoires des Sçavans Etrangers*.

The gas which he employed is that which floats on the ſurface of beer during its fermentation. He obſerves, that the atmoſphere of gas which riſes from this liquor fills all the upper part of the vat, in the bottom of which the beer ferments. The depth of the vat from its edge to the ſurface of the liquor was four feet, and this ſpace was filled with gas unmixed, or at leaſt, in a very ſmall degree, with air.

The *Duke de Chaulnes* plunged a jar into this ſtratum of gas, as one plunges a veſſel into the water contained in a baſon, and he withdrew it ſo full of gas, that a candle was extinguiſhed as ſoon as it came to be level with the edges of the jar. He then poured this gas into another jar of equal ſize, in the ſame manner as water or other liquors are poured from one veſſel into another. The gas deſcends by this eaſy operation from one jar to the other, ſo that a candle will now burn to the bottom of the firſt jar, and will be extinguiſhed as ſoon as it enters the ſecond. The greater gravity of the gas than of air is thus ſhewn in a ſtriking manner. Nothing can be more ſingular than this action of pouring from one veſſel into another, where nothing appears that is thus poured, and to ſee nevertheleſs a candle inſtantly become extinct, an animal die in a few ſeconds, and an alkali made to cryſtallize, when they are put into this ſecond jar, which does not ſeem to contain any thing.

He

Many other contrivances for the performance of particular experiments are deſcribed in the writings of Dr. Hales *(Statics)* Mr. Cavendiſh (*Philoſ. Tranſ.* 1766, 1767) Dr. Prieſtley (*Obſervations and Experiments on Air, three vols.*) and M. Lavoiſier (*Opuſculus phyſiques et chemiques, Vol. I.*)

He moiſtened the inner ſides of a jar with oil of tartar per deliquium, and poured into this jar ſome gas. In leſs than a minute, theſe ſides were covered with cryſtals.

By putting ſome cauſtic volatile alkali into a veſſel filled with gas, and well cloſed, he produced a vacuum, as appeared from the fall of the mercury of a barometer, inſerted into this veſſel.

He filled large ſtone-ware bottles with this gas, by holding them during ſome time in the vat over the ſurface of fermenting liquor, and having corked the bottles, ordered them to be carried to the academy, in preſence of whom he exhibited his experiments.

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A TREA-

A
TREATISE
ON THE
VARIOUS KINDS
OF
GAS.

CHAP. I.

Definition and Enumeration of Gaſes.

1. MOST, perhaps all, ſubſtances, ſolid and liquid, may, by heat, more or leſs intenſe, be converted into fluids exceedingly rare, inviſible, and highly elaſtic. Thus when water is expoſed to a heat ſufficient to raiſe the mercury in Fahrenheit's thermometer to 212°, if it be not ſubject to a greater preſſure than that of the atmoſphere, it becomes gradually changed into vapour, which is a fluid rare, inviſible, and highly elaſtic; and the water thus changed, while it continues expoſed to that temperature and preſſure, retains its elaſtic ſtate*.

Several

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* Whenever the vapour of water becomes viſible, the water is no longer in the ſtate of vapour; but is again *condenſed*, that is, reduced to its original ſtate of a liquid; as is explained in §. 2. For fogs, and viſible exhalations, are nothing but aſſemblages of very minute drops of water formed by the condenſation of vapour; which drops are ſo ſmall that they can ſcarcely overcome the re-

ſiſtance

Several ſubſtances which were formerly thought unalterable by fire, have been lately diſcovered to be ſuſceptible of evaporation, when expoſed to a heat ſufficiently intenſe. *Diamonds* have been lately ſhewn by the French Academicians to be evaporable by a heat not much more intenſe than that uſed in the cupellation of ſilver. Gold and ſilver are ſaid to have been elevated by the heat of a concave mirror †.

2. Many of the ſubſtances thus volatilized, or converted into a rare, inviſible and elaſtic fluid, by heat, may be again condenſed into concrete, or palpable and viſible ſubſtances, by expoſing them to a heat leſs intenſe than that which was neceſſary to produce their evaporation. Thus when the vapour of water is expoſed to ſome degree of heat leſs than 212°, it loſes its great elaſticity, and bulk; and is again *condenſed*, that is, reduced to its original ſtate of a liquid. All thoſe rare, inviſible and elaſtic fluids which may, by cold, or ſuch a degree of it as has been hitherto applied, be thus condenſed, are called *vapours*.

3. Several other highly elaſtic, inviſible, rare fluids cannot, by the cold of the atmoſphere, or by any degree of cold to which they have hitherto been known to be expoſed, be thus condenſed. Such is the *air* which we breathe, and ſuch are the *elaſtic fluids*, which eſcape from wine and other fermenting liquors, and from the effervescing mixtures of acids and alkalies.

Theſe

ſiſtance which the air makes to their deſcent, and therefore ſeem to be ſuſpended in that fluid. For their gravity being as their quantity of matter, and the reſiſtance of the air being as their ſurfaces, it follows, that the ſmaller the drops are, the more reſiſtance will be given to their deſcent through the atmoſphere.

† Buffon, Supplement, Tome 3me.

Theſe *Fluids* are called *permanently elaſtic*, becauſe they cannot, like thoſe mentioned in §. 2, be deprived of their elaſticity by cold *. They are alſo called Gas by *Van Helmont*, who diſcovered many of theſe permanently elaſtic fluids, and comprehended the whole genus of theſe fluids under this appellation; while he diſtinguiſhed the ſeveral ſpecies, by adding deſcriptive epithets to the generical term; as *gas ſylveſtre*, *gas ventoſum*, *gas flammeum*, &c. †

4. A Gas may therefore be *defined* "AN EXCEEDINGLY RARE, HIGHLY ELASTIC, INVISIBLE FLUID, "NOT CONDENSABLE BY COLD."

By this definition a Gas may be diſtinguiſhed from other ſubſtances. The elaſticity of gaſes is ſo great, that they can ſupport the weight of the incumbent atmoſphere, and yet remain ſo rare, that although ſome are denſer than others, yet they are all ſeveral hundred times lighter than water. They are diſtinguiſhed from *ſmoke* and other *viſible exhalations*, by their being inviſible, and alſo by their great elaſticity;

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* The Fluids called *permanently* elaſtic, may be fixed, abſorbed, or deprived of their elaſticity, by being combined with other ſubſtances. Thus the permanently elaſtic fluid obtained from calcareous earths, may be abſorbed by water, or by the quicklime that is diſſolved in lime-water; and when it is thus abſorbed and combined, it is reduced to a ſpace ſeveral hundred times leſs than that which it before occupied. And further, although theſe fluids retain their elaſticity in any degree of cold to which they have been expoſed, we cannot with certainty infer, that ſome of them might not be condenſed by a more intenſe cold. The *permanency* of the elaſticity, therefore, of theſe fluids is to be underſtood only as relative, 1ſt, to their uncombined ſtate, and, 2dly, to any degree of cold to which they have hitherto been known to be expoſed.

† See an enumeration of the principal gaſes obſerved by *Van Helmont*, in the preface to this Treatiſe.

and they are diſtinguiſhed from *vapours*, by their not being condenſable by cold.

5. The *various kinds of Gas* hitherto diſcovered, *native* or produced by *art*, are enumerated below. Theſe ſhall be treated ſucceſſively. Others will probably be diſcovered by means of future experiments and obſervations.

1. *Air.*
2. *Calcareous Gas.*
3. *Inflammable Gas.*
4. *Nitrous Gas.*
5. *Vitriolic acid Gas.*
6. *Marine acid Gas.*
7. *Nitrous acid Gas.*
8. *Fluor acid Gas.*
9. *Alkaline Gas.*

CHAP. II.

On Air.

6. AIR is the inviſible, inſipid, inodorous, pellucid, ſonorous, reſpirable, and permanently elaſtic fluid that ſurrounds our Globe. From the permanency of elaſticity, it is comprehended in the definition given (§. 4.) of Gaſes, of which it is therefore a ſpecies, and might be called *Atmoſpherical Gas*, in conformity with the mode which we have adopted of denoting the ſeveral ſpecies of permanently elaſtic fluids by deſcriptive epithets added to the generical word *Gas*; but the word *Air* having been immemorially applied to ſignify this fluid, we ſhall, in the following pages, employ it in this popular ſenſe, and ſhall confine it to denote the atmoſpherical fluid alone. And when I ſhall have occaſion to mention thoſe re-

ſpirable and permanently elaſtic fluids which may be obtained by certain artificial proceſſes, and to which the ſame name cannot be denied, as they poſſeſs all the known properties of air, I ſhall diſtinguiſh them from the atmoſpherical fluid, by adding the epithet *factitious* to the word *air* ‡. Phyſical writers have treated copiouſly on the gravity, elaſticity, and other mechanical qualities of air. Its *chemical* properties have been diſcuſſed at the article *Air* of the *Dictionary of Chemiſtry*. Here therefore ſome ſupplemental obſervations only ſhall be added, concerning its *affections* by *different ſubſtances*, and its *conſtitution*.

7. Air is capable of *combining with various ſubſtances*. Hence the atmoſphere is replete with diverſe exhalations, and with all thoſe matters which the air can diſſolve: and its properties are affected by the quantity and kind of foreign particles contained in it.

8. *Water* is one of thoſe ſubſtances which *Air is capable of diſſolving*; and accordingly more or leſs of this liquid is always contained in the atmoſphere; as appears from the moiſture imbibed by dry cauſtic alkali

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‡ The word *air* has been uſed by Mr. *Boyle*, Dr. *Hales*, Dr. *Black*, Mr. *Cavendiſh*, Dr. *Prieſtley*, and other Engliſh authors, to denote the whole genus of permanently elaſtic fluids, moſt of which differ widely, in their properties, from the atmoſpherical fluid. I have, in the preface, given my reaſons, for confining this word to its proper, antient and popular meaning, and for giving other names to the fluids which theſe authors have diſtinguiſhed by the terms, *fixed air*, *inflammable air*, *nitrous air*, &c. But to prevent any ambiguity that might ariſe from this difference of phraſeology, I have, in treating of each fluid, mentioned the names by which theſe authors have diſtinguiſhed it. Thus when they ſpeak of the fluid which is the ſubject of this chapter, they add to the word *Air*, (by which alone it is diſtinguiſhed in this Treatiſe) the epithets *common*, or, *reſpirable*.

alkali expoſed to air, or from the condenſation of moiſture on the external ſurface of a veſſel in which artificial cold is produced by mixture of ſalt and ſnow. Probably no part of the atmoſphere is ever free from a portion of diſſolved water, beſides the watery particles that float *viſibly*, (for water diſſolved in air is inviſible) forming clouds, and fogs; all which are mechanically ſuſpended in the lighter atmoſphere, as gold-leaf is in water, and not *chemically* combined with the air.

9. As water is capable of being diſſolved by air, and thereby diffuſed through the maſs of the atmoſphere, ſo alſo is *air capable of being abſorbed by water*, and the air thus abſorbed ſeems to loſe part of its elaſticity. Thus if water be deprived by boiling of all the air or other Gas contained in it, and afterwards be expoſed to the atmoſphere, it will abſorb ſome air. And if a bubble of air be admitted into an inverted bottle filled with boiled water, the whole quantity of air will be abſorbed, provided the bubble of air be not larger than is requiſite to ſaturate the quantity of water employed*.

The quantity of air capable of being abſorbed by a given quantity of water, is, according to Dr. *Hales*, equal in bulk to one fifty-fourth part, and according to *Nollet*, to one thirtieth part of the water employed†.

10. *Air*

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[*] This abſorption of air by water has been generally ſaid to occaſion no ſenſible encreaſe of the bulk of the liquid. *Muſchenbrook* however obſerves that the air abſorbed by water does add a very *little* to the bulk of the water; but that any difference it may produce in the ſpecific gravity of the liquid is ſo ſmall that it can ſcarcely be diſcovered by experiment. *Introd.* §. 1481.

[†] We need not wonder that a ſubſtance ſo rare and elaſtic as air ſhould be thus united to water, and by the union be deprived of the greateſt

10. *Air promotes the combuſtion of inflammable bodies*; and the air thus employed is *altered* by the operation. Thus when charcoal or other inflammable ſubſtance is burnt, the air in which this combuſtion happened, becomes poſſeſſed of properties very different from thoſe of common air.

11. *Air thus altered by burning ſubſtances becomes leſs in bulk* than it was before the alteration, as Mr. *Boyle* has obſerved. Thus, when lighted candles or other kindled ſubſtances are put under a receiver, the mouth of which is inverted and immerſed in a veſſel filled with water, they burn a little while, longer or ſhorter, according as the quantity of air is greater or leſs relatively to the quantity of ſubſtance actually in combuſtion at a time. When they have ceaſed to burn, the

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greateſt part of its elaſticity; this phenomenon being conſentaneous with the general analogy of chemical ſolutions or combinations. For in all chemical ſolutions, the integrant parts of one body are divided and ſeparated by thoſe of the other component body. Thus the particles of air are ſeparated from each other by the particles of water. But elaſticity or expanſive force cannot be conſidered as the property of any ſingle particle, for it implies two particles, at leaſt, endeavouring to recede from each other. The particles therefore of air being conſiderably disjoined from each other, and engaged with thoſe of water, may have their expanſive power ſo much weakened, that they yield to the combining power of water. The elaſticity however of air abſorbed by water is not deſtroyed, but only diminiſhed; for by the application of heat, or by removing the preſſure of the atmoſphere, the air gradually recovers its expanſive force, and diſengages itſelf from the water. Thus *M. de Luc* obſerved, when he was making thermometers with different liquors, that theſe liquors which had been deprived by boiling of much of their contained Air or other Gas, did nevertheleſs expand gradually, and riſe many degrees in the ſtems of the thermometers, when the preſſure of the atmoſphere was removed, and that this expanſion took place long before any bubbles appeared. See *Recherches ſur la modification de l'atmoſphere*, I. 230.

water within the receiver may be ſeen to riſe higher than it was before the combuſtion, as ſoon as the included air has loſt the heat which it had received from the burning ſubſtance. The greater height of the water within the receiver after the combuſtion, than before it, ſhews that the included air preſſes with leſs force on the ſurface of the water than the external air does; and conſequently that it is reduced to a ſmaller ſpace than it occupied before the combuſtion.

This *diminution of the preſſure*, or of the *bulk* of the quantity of air contained in the receiver, occaſioned by the combuſtion of inflammable ſubſtances, may depend upon a *diminution of the quantity* of this elaſtic fluid by *abſorption*, or by *precipitation* of part of it, or upon a *diminution merely of its elaſticity*, while the quantity remains the ſame. Dr. *Hales* conſiders it as a diminution of the elaſticity of the contained air: but Dr. *Prieſtley* is inclined to think, that it is a diminution of the quantity of air, ſome part being precipitated; and he is induced to form this opinion, from his not having been able to find any *conſiderable* alteration in the ſpecific gravity of the air in which candles or brimſtone had burnt. From ſeveral trials purpoſely made he thinks that this diminiſhed air was not heavier, but rather lighter than air which had not been diminiſhed. *Exp. and Obſ. on Air*, I. 46 *and* 267. II. 94.

Dr. *Hales* obſerved that the *air continued to diminiſh* under the receiver ſeveral days after the extinction of the candles. This continued diminution may probably have been occaſioned by a gradual abſorption of ſome part of the air by the water in which the inverted receiver was immerſed; for Dr. *Prieſtley* remarks, that "this diminution of air by burning is not always im-
"mediately apparent, till the air has paſſed ſeveral
" times

" times through water; and that when the experi-
" ment was made with veſſels ſtanding in quickſilver
" inſtead of water, the diminution was generally in-
" conſiderable till the air had paſſed through water."
Exper. and Obſerv. on Air, vol. I. 46.

Air altered by burning ſubſtances occaſions *a precipitation in lime-water*. It appears therefore that by combuſtion ſome Gas is produced which is capable of uniting with the quicklime diſſolved in the lime-water; and is probably the ſame which will be deſcribed in chap. 3d. under the name of *Calcareous Gas*. Whether this Gas proceeds from the combuſtible body employed, or from ſome precipitation of part of the air, or be a compound reſulting from the union of ſome part of the inflammable body with the air or any of its component parts, has not yet been aſcertained*. When this Gas has been abſorbed by water or by lime-water, the remaining part of the air is alſo noxious and unfit for maintaining flame.

Air diminiſhed by burning ſubſtances is no longer capable of maintaining fire. Dr. *Deſaguliers* obſerves that Air which had paſſed through burning coals into an exhauſted receiver immediately extinguiſhed flame.

Air is not capable of ſuffering more than a limited diminution by burning ſubſtances. The diminution of the bulk of a quantity of air included in a receiver in which a candle was allowed to burn as long as it could, was found by Dr. *Hales* to be equal to one twenty-ſixth part of the whole quantity of included air, and by Dr. *Mayow*

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* This Gas cannot be produced from an inflammable body merely by heat without combuſtion; for when the focus of a burning glaſs was thrown on a bit of charcoal ſuſpended in a receiver filled with any other Gas than air, and inverted into a veſſel containing lime-water, no precipitation was occaſioned in the lime-water. *Exp. and Obſ.* I. 136.

Mayow to be one thirtieth, and by Dr. *Prieſtley* to be one fifteenth or one ſixteenth. This diminution is obſerved to vary in different circumſtances. Dr. *Hales* obſerved that air ſuffered a greater diminution in equal receivers by large, than by ſmall candles; and alſo with equal candles, in ſmall, than in large receivers. Probably the candles become extinct as ſoon as all the air in contact with, or near their flame, has ſuffered its alteration; for by other modes of combuſtion, the air has been made to ſuffer a much greater diminution. Thus Mr. *Cavendiſh* found that air was diminiſhed one tenth by paſſing through an iron tube filled with red-hot powder of charcoal. *Exp. and Obſ. vol. I.* 129.

And Dr. *Prieſtley* has diminiſhed the air much more by throwing the focus of a lens, or of a concave mirror, upon a bit of charcoal ſuſpended in a receiver. *Id. p.* 47.

I have produced a diminution equal to one ſixth part of the included air by making the candle while it burns move quickly through the different parts of the inverted receiver, and thereby bringing the flame into contact with more of the air, than when the candle remains in one ſituation till it becomes extinct.

12. *Air promotes the calcination of Metals*; and it is alſo diminiſhed by this operation, which is conſidered by Chemiſts as a ſpecies of ſlow combuſtion.

This diminution, like that effected by burning ſubſtances, *cannot be carried beyond a certain proportion to the whole quantity of air employed.* Accordingly, Father *Beccaria* found by expoſing filings of lead and tin to heat in veſſels hermetically ſealed, that only a part of theſe metals could be calcined, and that this part was proportionable to the capacity of the veſſels employed. [*Mem. de l'Acad. de Turin* 11.]

After the air has ſuffered its utmoſt diminution by calcining metals, it is no longer capable of promoting any further calcination.

The *diminution of Air by the calcination of metals* has been found by Dr. *Prieſtley* to be equal to one fourth of the whole quantity of air employed. Vol. I. p. 134.* But M. *Lavoiſier* eſtimates this diminution only at one fifteenth or one ſixteenth.

Air diminiſhed by calcination differs from the air diminiſhed by burning ſubſtances in this reſpect, that it *does not occaſion a precipitation in lime-water*, the reaſon of which difference is aſſigned by Dr. *Prieſtley* to be, that the calx ſeizes the part of the air, which is precipitated, in preference to the lime. Vol. I. p. 136.

The water however over which metals have been calcined acquires a yellowiſh tinge, and an exceedingly pungent ſmell and taſte. *Id.* 135.

13. *Metals acquire weight by calcination*, and the air which has aſſiſted in this proceſs, is thereby diminiſhed. Theſe facts ſeem to ſhew that ſomething is abſorbed during calcination by metals from the air †.

This abſorption of air, or of ſome part of air, is further rendered probable from the elaſtic fluid that has been obſerved to eſcape during the reduction or revival of metallic calxes, and from the loſs of weight ſuſtained by them during that operation.

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* This very great diminution of air was effected by throwing the focus of a burning mirror or lens upon bits of lead and tin ſuſpended in a glaſs receiver.

† The firſt perſon who aſcribed the acquiſition of weight by calcining metals to the abſorption of air was *Jean Rey*, who has written expreſsly on this ſubject, in a book entitled, *Eſſais de Jean Rey Docteur en Medicine, ſur la recherche de la cauſe pour laquelle l'Etain et le plomb augmente de poids, quand on les calcine.* A Bazas 1630. This author attributes the encreaſe of weight to the adheſion of the denſer part of the air to the calxes, while the more ſubtile part of this fluid, which prevents the adheſion of the air to other ſubſtances, is ſeparated during the calcination.

14. *Air* is *diminiſhed* by exhalations of *liver of ſulphur*, and of various *inflammable ſubſtances.*

Mr. *Boyle* relates that a quantity of *air was totally abſorbed by oil of turpentine* and *ſpirit of wine* mixed together. [*Boyle's works, vol. V. p.* 113.] Dr. *Prieſtley* has alſo found that oil of turpentine poſſeſſes the power of diminiſhing air in ſo great a degree, that in one experiment one fourth only, and in another experiment only one ſixth of the original quantity of air remained. *Vol. III. p.* 92. Dr. *Hales* found that air was abſorbed by the *pyrophorus of Homberg*; and Dr. *Prieſtley* obſerved that diminutions of air were occaſioned by *liver of ſulphur*; by a cement compoſed of *turpentine and bees wax*; by *white paint*; and by *red lead and oil.* Vol. II. p. 182.

Dr. *Hales* found that a mixture of *ſulphur and filings of iron* formed into a paſte with water diminiſhed air; and the diminution has been eſtimated by Dr. *Prieſtley* to be equal to one fourth or one fifth of the air employed. [*Exp. and Obſerv. vol. I. p.* 105.] This diminution was equal, whether the experiment was made over mercury or over water. The diminiſhed air was found to be lighter than pure air; and it did not precipitate lime-water; the cauſe of which has been attributed to the acid of the ſulphur diſſolving the lime, and thereby preventing its precipitation. [*Exp. and Obſerv. vol. I. p.* 105.]

15. *Air is diminiſhed by expoſure to putrefying ſubſtances.* At firſt an elaſtic fluid is frequently generated, by which the bulk of the air is encreaſed*, but in

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* *See Chap. XI.*

eight or ten days, the air is reduced to about four fifths or five ſixths of its original dimenſions. [*Id. vol. I. p.* 78.]

16. *Air is diminiſhed by reſpiration of animals*, as Mr. *Boyle* firſt obſerved. Vol. IV. p. 122. The diminution was found by Dr. *Hales* to be about one thirteenth of the whole air employed.

Air diminiſhed by reſpiration *precipitates the lime contained in the lime-water*, as Dr. *Macbride* obſerved.

17. Various other ſubſtances and mixtures have been obſerved to diminiſh air, among which are the following:

a. Lime mixed with *water*. *Hales.*

b. Lime mixed with *Sal Ammoniac*. *Hales.*

c. Lime mixed with *Acids*. *Hales.*

d. Marine acid extricated by pouring vitriolic acid on ſea-ſalt, or on ſal ammoniac. At firſt ſome fluid was generated, probably that which is treated of in Chap. VII. under the name of *Marine acid gas.*

e. Volatile alkali mixed with *iron*. *Hales.*

f. Volatile alkali mixed with *copper*. *Hales.*

g. Iron filings mixed with *water*. *Hales.* M. *Lavoiſier* found that the diminution of air by iron-filings and water amounted to one fourth part of the air in the ſpace of two months; and Dr. *Prieſtley* obſerved, that the air thus diminiſhed could not be further diminiſhed by nitrous gas. *Exp. and Obſ. vol. II. p.* 182.

h. Dr. *Hales* obſerved that air was diminiſhed in the *diſtillation of aqua-fortis*, and by the mixture of *aqua-fortis* with *copper ore*, or with *pyrites*, or with *coal.* And Dr. *Prieſtley* has found, that even the pure colourleſs nitrous acid vapour does, in length of time, phlogiſticate air.

i. Volatile ſal ammoniac during its ſublimation. *Hales.*

k. Sulphur ſubliming. Hales.

l. Vinous Gas. Boyle III. 144. *See Chap. III.* §. 35.

m. Nitrous Gas. Hales. See Chap. V.

n. Electric ſparks. The electric ſpark being made to paſs through a quantity of air included in a glaſs tube, in which alſo was contained ſome water tinged blue with turnſole, diminiſhed the air one fifth, and changed the blue colour of the liquid to a red. *Exp. and Obſ. vol. I. p.* 184. When the electric ſpark was taken in air over lime-water, the lime was precipitated. *Id.* 186. And when the electric ſpark was taken in air and in a veſſel containing ſome cauſtic vegetable alkali, the alkali became cryſtallized. *Rozier. Aug.* 1777.

o. Concentrated vinegar. Exp. and Obſ. vol. II. p. 27.

p. Nitre, which has been melted, during its cooling, was obſerved by Dr. *Prieſtley* to injure common air. *Vol. II.* 167.

q. Vitriolic acid Gas was obſerved by Dr. *Prieſtley* to injure common air. *Vol. II.* 209. See Ch. VI.

r. Bolognian Phoſphorus diminiſhes and phlogiſticates air in a remarkable degree. But the *Phoſphorus of Urine* produced this effect very ſlowly and in a ſmall degree, as has been obſerved by *Signor Alexander Volta*. Exp. and Obſerv. vol. III. 381.

s. Air is diminiſhed by *Diamonds* expoſed to violent heat. M. *Lavoiſier* obſerved that 60 cubic inches of air, in which four grains and a half of diamonds were expoſed during 16 minutes to the focus of Tſchirnhauſen's great lens, ſuffered a diminution of eight cubic inches. The air thus diminiſhed precipitated the lime contained in lime-water. *Mem. de l'Acad.*

des Sciences à Paris, 1772. This experiment, together with the flame obſerved in diamonds expoſed to heat under a muffle, and the preſervation of diamonds in the fire by inveloping them in powdered charcoal, ſeem to decide the queſtion, lately agitated in France, in the affirmative, whether the effect of fire on diamonds be a real combuſtion. *See the Dictionary of Chemiſtry, article Diamonds.*

18. Air which has been once diminiſhed to its utmoſt by any one of theſe proceſſes cannot be further diminiſhed by a repetition of that proceſs, or by any of the other diminiſhing proceſſes. *Exper. and Obſervat. vol. I.* 132.

19. Air may be *totally* and almoſt *inſtantaneouſly* abſorbed by *charcoal* heated red-hot, or which has been heated red-hot, and extinguiſhed without expoſure to air in quickſilver. The quantity of air which may be thus abſorbed or devoured is many times the bulk of the charcoal employed. The ſame effect is produced by charcoal, thus prepared, upon the other permanently elaſtic fluids. This very aſtoniſhing fact has been lately diſcovered by the *Abbé Fontana*, and communicated to me by Dr. *Prieſtley*. In order to repeat this experiment, let a jar partly filled with quickſilver and partly with air, or other elaſtic fluid, be inverted into a baſon of quickſilver, and let pieces of charcoal, which have been previouſly made red-hot and extinguiſhed in quickſilver, and which have not been expoſed to air, be ſlipped under the jar, in which it will aſcend through the quickſilver till it comes into contact with the air included in the jar, part or all of which air, according to its quantity relatively to the quantity of charcoal, will almoſt inſtantaneouſly diſappear. The *Abbé Fontana* has made many

experiments in conſequence of this diſcovery, a relation of which, whenever he publiſhes them, cannot fail of being very intereſting.

20. *Air is neceſſary to animal life*, as is well known from the fatal effects of encloſing animals in exhauſted receivers, or in receivers filled with any other gas or vapour. Some inſects however are ſaid to live well in vacuo. *Muſchenb. Introd. ad Phil. Nat.* §. 2167.

The air that has once ſerved for the reſpiration of animals is unfit to be again reſpired, and is *fatal to life*. The *quantity* of air employed for reſpiration by a man is computed by Dr. *Hales* to be a *gallon* in every *minute*.

From the noxious quality of reſpired air, may we not explain the facts related by travellers, that animals are killed by the breath of whales, and eſpecially by the breath of an immenſe ſerpent that inhabits the banks of the river Amazon*; the air reſpired by theſe very large creatures being ſufficient totally to invelope ſmaller animals, and to exclude the air during a ſmall portion of time, which, however, is ſufficient for this noxious air to produce its fatal effect? If it be objected, that air, by having been reſpired only once, does not appear, from experiments hitherto made, to be ſo far vitiated, as to become capable of deſtroying life; may it not be anſwered, that the air, by being expoſed to a much greater ſurface of lungs, and perhaps during a longer time, in theſe very large animals than in men, may probably ſuffer a much greater degree of injury, and be more completely phlogiſticated? Perhaps alſo the effluvium and ſmell of the breath of theſe large animals may be peculiarly offenſive to the organs of ſenſation of other animals, which they may affect in the ſame manner as the exhalations, deſcribed in §. 22. do when reſpired.

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* See *Don Ulloa's Voyage.*

The more denſe the air is, the longer it is capable of ſuſtaining the life of animals, as appears from the experiments of Mr. *Boyle*. Nevertheleſs, a *rarefied air*, provided it be frequently renewed, ſuſtains life very well. *Condamine* lived ſeveral weeks upon the Peruvian mountains, where the air was ſo rare that the mercury of the barometer was no higher than fifteen inches and nine lines[*]. An *air* alſo *exceedingly denſe* may be with ſafety reſpired. Divers ſometimes breathe under bells an air nine times denſer than the air of the atmoſphere.

21. Not only the air diminiſhed by reſpiration is *noxious* to animals; but alſo the *air in which inflammable ſubſtances have burnt*; the air in which *hepar of ſulphur*, and *fumes of inflammable ſubſtances* have exhaled; the air in which ſubſtances have undergone the *putrefactive fermentation*, and probably all other kinds of *diminiſhed air*, are *noxious* to animal life [†], *extinguiſh flame* [†], and are incapable of *diminiſhing nitrous gas*, which is a diſtinguiſhing property of air.

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[*] See *Bouger's Voyage to Peru.*

[†] Nevertheleſs, Mr. *Boyle* obſerved that animals lived *nearly* as long in air in which candles had burnt, as in the ſame quantity of freſh air, and Dr. *Prieſtley* confirms the obſervation by his own experiments. Hence it appears that animals can bear a greater degree of depravity of air than is generally occaſioned by the burning of candles. But although flame be generally extinguiſhed when the air has ſuffered an inconſiderable diminution, yet by throwing the focus of ſolar rays on a bit of charcoal, the air may, by means of combuſtion thus promoted, be diminiſhed as much as it can by any other method, that is, one fifth of the whole quantity, as Dr. *Prieſtley* has ſhewn.——It cannot be doubted, that air thus diminiſhed as much as it can be by burning ſubſtances, is noxious and fatal to animal life. See §. 11.

From the many inſtances of the diminution of air by combuſtion, calcination and other proceſſes, in which the phlogiſton contained in bodies is ſuppoſed to be ſeparated from them, or merely by expoſing air to phlogiſtic vapours, it appears that the alteration produced in the air is effected by the phlogiſton of theſe bodies combining with the air, or otherwiſe operating upon this fluid: and the air thus altered is accordingly called *phlogiſticated air*. With this phlogiſticated air is generally mixed a ſmall portion of a gas which precipitates the lime contained in lime-water, and therefore ſeems to be the ſame which will be deſcribed in *chap*. III. under the name of *calcareous Gas*. And although in ſome inſtances, as in the calcination of metals, this gas does not appear, yet we cannot thence infer that it is not produced, becauſe it may be abſorbed by the calcining metals, or other ſubſtances employed. *See* §. 11 *and* 12.

22. Almoſt all exhalations, vapours, and fumes, when in conſiderable quantity, make the air unfit for reſpiration. The vapour of pure water threw a bird into great anxiety; the vapour of vinegar had the ſame effect; vapour of ſpirit of wine killed a bird; and the vapours of oil of turpentine, oil of olives and of ſpirit of ſal ammoniac, were alſo found to be fatal to life. *Muſchenb. Introd. ad Philoſ. Nat.* §. 2049. The vapour of newly plaſtered walls and of granaries are known to be noxious. *Laghius* found that the ſmell of camphor and of muſk was fatal to animals. *Comm. Bonon, tom.* 3. We ſhall hereafter ſee that every ſpecies of Gas, air excepted, is noxious; and, they have been all obſerved to be more ſuddenly fatal than a vacuum is: hence, it is evident, that their noxious quality does not depend merely on their preventing

the acceſs of air, or from their want of any principle, which may be ſuppoſed to render air neceſſary to life, but alſo from ſome inſtant and immediate effect on the organs of ſenſation. Animals may be rendered leſs ſenſible of the diſagreeable impreſſion, and leſs liable to be injured, by being gradually habituated to it, as Dr. *Prieſtley* has obſerved. *Exper. and Obſervat. vol. I.* 72.

23. Some attempts have been made to *reſtore vitiated air*, and render it again fit for reſpiration. Dr. *Hales* ſays that he cleanſed air, which had been reſpired, by making it paſs through flannel imbibed with ſalt of tartar; and that he prolonged the combuſtion of a candle in a given quantity of air by the ſame operation. The flannel employed gained weight, probably by abſorbing the calcareous gas which is produced by combuſtion or by reſpiration, as has been obſerved, §. 11 and 21. But as in air vitiated by reſpiration or by burning ſubſtances, not only this calcareous gas is noxious, but alſo the reſiduum after this gas has been ſeparated by being abſorbed in water, is found to extinguiſh flame, and to be incapable of ſuſtaining life, the above method of Dr. *Hales* cannot be very effectual. Dr. *Prieſtley* ſays, that by *long-continued agitation in water*, he has reſtored air vitiated by reſpiration, putrefaction, combuſtion, calcination of metals, a mixture of filings of iron with ſulphur, or by white paint. Was this melioration produced by the water ſeparating the vitiated part of the air from the reſt by abſorption; or by the agitation effecting a kind of circulation between the external air and the vitiated air included in the jars, by which means much of the former might be received into the veſſels, while part of the latter might

be abſorbed by the water and thrown out into the open air ‡?

The *Count de Saluces* pretends, that air injured by combuſtion can be meliorated by *cold* and by *compreſſion*. But Dr. *Prieſtley*, from experiments purpoſely made, has refuted that pretenſion. *Exp. and Obſ. vol. I.* 48.

24. *Air is neceſſary to vegetation* or the *life of plants*. In vacuo, plants do not grow, and ſeeds buried too deep under ground do not vegetate.

M. *Cygna* affirms that plants included in a given quantity of air diminiſh this fluid, and ſoon languiſh and die; and that if other plants be afterwards introduced into the ſame receiver, they preſently die without occaſioning a further diminution of the air. Nevertheleſs, it appears from Dr. *Prieſtley*'s experiments that plants can live long in confined air without ſenſibly diminiſhing or rendering the air unfit for maintaining flame or animal life. A ſprig of mint having been put into a glaſs jar inverted into a veſſel of water, during ſome months, the air was found not to be vitiated. *Exp. and Obſ. vol. I.* 5.

Dr. *Prieſtley* found that plants grew not only in confined air, but alſo in air vitiated by the flame of a candle, or by reſpiration: and even that the vitiated air was frequently reſtored, or at leaſt meliorated by the vegetation of the included plants. He put ſprigs of mint growing in water into different veſſels filled with air, in ſome of which candles had burnt till they ſpontaneouſly became extinct, and in others the contained air had been reſpired, and he found that after the plants had been growing a few days, the contained air was ſo much meliorated that candles burnt in it, and animals could reſpire it. (*Vol. I. p.* 51.) From theſe experiments he infers, that *vegetation is one of the means employed by nature to purify air tainted with reſpiration, putrefaction, or combuſtion* *.

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‡ Dr. *Prieſtley* has found that pure air is conſiderably depraved by agitation in the pureſt water. *Vol. II.* 96.

But plants can tolerate only a certain degree of injury to the air in which they are placed; for Dr. *Prieſtley* relates, that when growing ſprigs of mint were put into air ſtrongly and recently tainted with putrefaction, they *preſently died.* Vol. I. p. 86.

It is not however improbable that plants are capable of reſiſting a certain and even a conſiderable degree of putrid taint infecting the air; for ſeveral kinds of plants and alſo animals are known to inhabit thoſe places chiefly where a putrid effluvium prevails, which they ſuſtain without injury, and even perhaps with advantage to

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* Dr. *Prieſtley* has, ſince his laſt publication on air, been ſo obliging as to acquaint me, that his late experiments confirm his opinion of the power of vegetation in purifying the atmoſpherical fluid, although he acknowledges, with his uſual candour, that he has alſo met with many exceptions. He has not only meliorated phlogiſticated air, by means of growing plants, but he has alſo, by the ſame means, greatly encreaſed the purity of atmoſpherical air, ſo as to make it approach to the ſtate of the pure factitious airs deſcribed in the following part of this chapter. Among the many diſcoveries with which the labours of this zealous and ſagacious philoſopher are in a ſingular manner crowned, one of the moſt extraordinary is, that a green matter, which adheres to the ſides of veſſels filled with water, does, in a few hours after it is put under an inverted jar full of water, emit a conſiderable quantity of *pure* air, like thoſe airs obtained by factitious proceſſes deſcribed in the following part of this chapter. He has alſo found that the air contained in the bladders of ſeveral kinds of ſea-weeds, while the plants are freſh, is conſiderably better than atmoſpherical air. In the *Epilobium hirſutum*, or the *Willow plant*, he has diſcovered a ſingular property which it poſſeſſes, namely, that of *abſorbing* conſiderable quantities of air, and of other permanently elaſtic fluids.

to their peculiar conſtitutions. Further, animals and vegetables, while living, ſeem to poſſeſs ſome peculiar property of reſiſting putrefaction. For animals are known to live many days without food, and without any appearance of putrefaction, which however begins to take place a few hours after death. Alſo, vegetables are endowed with a ſimilar power; for the water in which plants grow, though it contain much vegetable putreſcent matter, does never putrify, while the plants live and are in health; but no ſooner is the life or the health of the plant deſtroyed, than the putrefaction begins. This fact is popularly known to perſons who keep ſprigs of mint, hyacinths or other flowers, growing in glaſs veſſels filled with water.

Hence the plants which grow in ſtagnant waters probably retard the corruption of theſe waters. *See Exp. and Obſerv. vol. II. p.* 185; where an inſtance is given of the water of a reſervoir becoming putrid, when the reſervoir was cleanſed from the vegetable matters which grew on its ſurface and its ſides, and did not recover its ſweetneſs till more vegetable matter again appeared.

Perhaps this important fact in animal and vegetable economy may be explained, by ſaying, that *fermenting* ſubſtances do generally aſſimilate to their own nature, in a certain degree, many other ſubſtances, with which they happen to be mixed; and that the fermentations which are continually proceeding in the fluids of living animals and vegetables, overcome the putrid or other noxious ferments, if theſe be not too ſtrong, in the ſame manner as the vinous fermentation reſiſts putrefaction, according to the experiments of Sir *John Pringle* and Dr. *Macbride*. Hence the more ſtrongly theſe natural fermentations proceed, that is, the more powerful is the *vis vitæ* of animals and plants, the more eaſily are noxious ferments overcome, and infections reſiſted.

The purification or melioration of the tainted air included in receivers in which growing plants were placed, may be attributed not only to the abſorption of the noxious vapour by the plants themſelves, but in ſome meaſure alſo, to the abſorption of this effluvium by the water in which the receiver was inverted, and more conſiderably by the watery vapours or perſpiration exhaled from the plant itſelf, which are known to be very great relatively to the ſmall ſpace within the receiver. Theſe vapours may be conſidered as water with an exceedingly enlarged ſurface, and therefore capable of producing its utmoſt effect by abſorption of the diffuſed noxious ſubſtance. The vitiated particles being thus abſorbed by the watery vapours floating in the receiver might have been precipitated when the vapours were condenſed by the evening colds; and by the conſtant ſucceſſion of evaporation and condenſation, which muſt have taken place in the receiver, the whole quantity of ſuch particles may have been abſorbed and precipitated, and the remaining air thereby purified.

While therefore we accede to the inference drawn by Dr. *Prieſtley* from his very curious experiments, that "VEGETATION is one of the means employed by "nature to purify air tainted by reſpiration, putrefac-"tion, or by combuſtion;" may we not aſcribe a conſiderable ſhare of this grand and important effect to EVAPORATION, whoſe operation is more extenſive, penetrates to greater heights, prevails on the middle of the ocean and in frozen regions where few vegetables appear; and may not plants be alſo conducive to this effect in a great meaſure by exhaling vapours abundantly, and be, in this reſpect, conſidered as inſtruments of evaporation ?

The vitiated particles in the air thus abſorbed by the copious vapours which exhale from the ſurface of the earth and of the ocean, are raiſed along with theſe into the higher regions of the atmoſphere, and thence again fall along with the condenſed vapours or rain upon the earth. Thus diffuſed and united with water, perhaps reſolved into their component parts, they are not hurtful to animals and vegetables, but enter probably along with the water into their veſſels, combine with their fluids, and conſtitute part of their ſubſtance. From the animal and vegetable matters, theſe particles may be again expelled by various fermentations, putrefaction, and combuſtion ; and thus, like moſt other kinds of matter, may undergo a perpetual circulation.

25. Several methods have been diſcovered by which *air*, or, at leaſt, fluids poſſeſſing all the known properties of the atmoſpherical fluid, may be *produced by art*. For this important diſcovery, which leads to a knowledge of the conſtitution of the atmoſphere, we are indebted to Dr. *Prieſtley*.

He found, that after he had abſorbed by long-continued agitation in water as much as he could of the ſeveral kinds of gas, ſuch as the inflammable gas, and that obtained by mixture of calcareous or alkaline ſubſtances with acids, (called by him and other Authors *fixed Air)* that the reſiduums had the properties of air, and he thence infers that *common air is thus generated* *. Exp. and Obſ. vol. I. p. 40. 68.

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* This inference ſeemed to me to be liable to two objections. 1. In the apparatus deſcribed for procuring theſe gaſes, there muſt always have been ſome ſmall portion of common air mixed with the

26. By expoſing *red lead*, or *calcined mercury*, to the focus of a burning glaſs, Dr. *Prieſtley* expelled from theſe ſubſtances a permanently elaſtic fluid, which not only poſſeſſed all the known properties of atmoſpherical air, but in which all theſe properties appeared in a more eminent degree than in the atmoſpherical

fluid

the gas. [*See Plate*, *fig*. 1.] 2. By a long-continued agitation of the gas in water expoſed to the atmoſphere, there would probably be ſome particles of external air continually abſorbed by the water, and afterwards ſeparated from the water into the veſſel containing the gas. In order to obviate theſe objections, I procured ſome gas from chalk and oil of vitriol, by means of an apparatus previouſly filled with boiled water, ſo that no air could be mixed with the gas obtained ; [*ſee Plate*, *fig*. 2. *and explanation* ;] and I let the gas remain expoſed to a conſiderable ſurface of clean boiled water till nine tenths were abſorbed by the water, without agitation. I paſſed this reſiduum four times through lime-water, till it occaſioned no more precipitation of the lime, by which operation, it was further reduced to a third, that is, to a 30th of its original quantity. This laſt reſiduum I found to be air ſo pure, that a candle burned in it, and that it diminiſhed as much nitrous gas as common air does. This production of air from calcareous and alkaline ſubſtances, is a very remarkable phenomenon, and deſerves further inveſtigation. I found that the reſiduum of gas obtained from pot aſh, and treated in the ſame manner as I had done that from chalk, had the ſame properties. The reſiduum of a gas obtained by diſtilling cream of tartar was chiefly inflammable, but ſeemed to contain ſome portion alſo of air, for a ſmall diminution was obſerved upon mixing it with nitrous gas.

But air cannot be thus produced from every one of thoſe gaſes, which, from the property they poſſeſs of precipitating the lime contained in lime-water, have been conſidered as of the ſame kind with the gas obtained from calcareous and alkaline ſubſtances, and have been comprehended under the general name of *fixed Air*. At leaſt, I found that a gas obtained by diſtilling green vitriol, which extinguiſhed flame, and precipitated the lime contained in lime-water, till it could no longer occaſion any precipitation in lime-water, left a reſiduum which extinguiſhed flame, and did not in any degree diminiſh nitrous gas, and was therefore ſimilar in its properties to the fluid called *phlogiſticated Air*.

fluid itſelf. For this factitious air did not only maintain the flame of kindled inflammable ſubſtances, but when a lighted candle or other ignited combuſtible ſubſtance was put into a veſſel containing this air, the flame was remarkably brighter, the combuſtion more rapidly excited, and a deflagration appeared ſimilar to that produced by thoſe mixtures of nitre and inflammable matters which are uſed in fire-works: Alſo, when animals were put into this factitious air, their reſpiration was much longer continued; that is, they could live much longer in a given quantity of it, than in atmoſpherical air. The diminution of nitrous gas (which is ſhewn to be a property of air, and to be an exact teſt of the purity of air, in *chap. V.*) was much greater; and the exploſion of inflammable gas much louder, by means of the factitious air, than when equal quantities of atmoſpherical air were mixed with theſe fluids. And the difference between the factitious and the atmoſpherical air appeared to be ſo great, that Dr. *Prieſtley* computes, that the former is capable of producing five or ſix times the effect of the latter fluid, in all theſe inſtances. He therefore conſiders this factitious fluid as a true and pure air, and thinks that the purity of the atmoſpherical air has been injured by the vapours with which it is always more or leſs mixed. He chiefly attributes the contamination of atmoſpherical air to the phlogiſton contained in the vapours mixed with the air, and the greater purity of the factitious fluid to the abſence of ſuch phlogiſtic vapours: accordingly, he diſtinguiſhes this factitious fluid and others of the ſame nature, which will be preſently deſcribed, by the name of *dephlogiſticated Air*.

27. The production of pure factitious air from red lead is much facilitated by addition of concentrated vitriolic acid. I put

I put 48 pennyweights of red lead into a long-necked retort, the contents of which were ten cubic inches; (*ſee Plate*, *fig*. 1. E.) and upon this red lead I poured twenty-four pennyweights of oil of vitriol. The red lead had been previouſly moiſtened with a little water, that the acid might more uniformly diffuſe itſelf through the red lead. The noſe of the retort was then immerſed under water, and over it an inverted jar filled with water was placed. The mixture of red lead and vitriolic acid became very hot, and ten cubic inches of air were ſoon thrown into the jar, without the application of external heat. Upon applying the flame of a lamp to the bottom of the retort, more air paſſed copiouſly into the jars. The quantity of air expelled from the above mixture of vitriolic acid and red lead, was found to be 36 cubic inches, after the proper allowances for the air contained in the retort had been made. If we ſuppoſe this air to be of the ſame denſity as atmoſpherical air, we ſhall find that the weight of the air obtained is about one hundredth part of the weight of the red lead employed *.

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* In the firſt Edition of this Treatiſe, I ſaid that a greater quantity of pure air might be obtained by adding vitriolic acid to red lead, than from an equal quantity of red lead alone, merely by violent heat. But Dr. *Prieſtley* has ſince been ſo obliging as to acquaint me, that he can produce as much air without addition of vitriolic acid as with it: which ſhews that the acid does not contribute to the formation of the air, as it ſeems to do in the inſtances of turbith mineral and other vitriolic ſalts, mentioned hereafter in §. 31. Nevertheleſs, the two proceſſes of obtaining air from red lead with or without vitriolic acid, are very different, and are ſimilar to the expulſion of calcareous gas, from calcareous ſubſtances by heat or by acids. For the expulſion of air from red lead is ſo much facilitated by addition of vitriolic acid, that much of the air eſcapes before any other heat is applied, than what ariſes from the mixture

28. A pure factitious air, poſſeſſed of all the known properties of atmoſpherical air, in a more eminent degree than the atmoſpherical fluid itſelf poſſeſſes theſe properties, and ſimilar in all its effects to the factitious air above deſcribed, (§. 26.) may be copiouſly obtained by means of heat from *nitrous acid* mixed with almoſt any unphlogiſticated earthy ſubſtance, as *minium*, *flowers of zinc*, *chalk*, *clay*, *gypſum*, mag-

mixture of theſe two ſubſtances, and the operation may be eaſily completed by the heat which glaſs veſſels can ſuſtain. The air thus produced (as in every other inſtance of the production of pure air) is always mixed with a very ſmall portion of calcareous gas, and which may be ſeparated by making the air paſs through lime-water, or, more effectually, through water in which ſome pieces of quick-lime are put; for as ſoon as the gas uniting with the lime diſſolved in the water precipitates this portion of lime, the water becomes capable of diſſolving a freſh portion of the lime; and thus the water is always kept ſaturated with the lime, notwithſtanding the precipitation produced in it. If pure factitious air ſhould be hereafter applied to medicinal purpoſes, this method of obtaining it ſeems preferable to thoſe hereafter mentioned by means of the nitrous acid; in which methods, not only a larger portion of calcareous gas is generally mixed with the pure air, but alſo conſiderable quantities of another noxious gas, namely, that which is deſcribed in chap. V. under the name of *nitrous*, are often produced, and which injure the purity of the factitious air. This method of obtaining pure air ſeems alſo to be preferable to thoſe in which the air is expelled from red lead and other ſubſtances merely by heat, becauſe theſe ſubſtances muſt be put into a gun-barrel, or other metallic veſſel; and it is known that metals expoſed to heat phlogiſticate air, and ſometimes emit a noxious inflammable gas. And when we conſider that this pure factitious air, by whatever means it is obtained, is capable of producing five or ſix times the effect of atmoſpherical air in every inſtance in which air is known to exert its peculiar properties, it cannot be doubted, that the breathing of this air, during ſome longer or ſhorter time, muſt produce ſenſible effects in the animal economy. The inveſtigation of theſe effects ſeems to be worthy of the attention of phyſicians.

magneſia alba, *wood aſhes*, *flints*, and *Muſcovy talc*, as Dr. *Prieſtley* has very happily diſcovered. *Vol. II. p.* 69, &c. He moiſtened any of the above-mentioned earthy ſubſtances with ſpirit of nitre, and put the ſubſtance thus moiſtened into a gun-barrel, or into a phial, into the neck of which was ground a bent glaſs tube. *See Plate*, *fig.* 1. C D B. He immerſed the noſe of the gun-barrel or of the glaſs tube into water, and placed over it an inverted jar filled with water. Upon applying heat to the part of the gun-barrel which contained the mixture, or to the bottom of the phial, an elaſtic fluid was expelled from the mixture and it paſſed into the inverted jar. By changing the jar frequently, he was able to examine the fluid expelled at different periods of the proceſs. Thus he obtained from mixtures of each of the above-mentioned earthy ſubſtances with nitrous acid, conſiderable quantities of air, ſome part of which he found to be very pure, and other parts to be mixed with calcareous and with nitrous gas, deſcribed in *chap. III.* and *V.* In the further proſecution of his experiments he obtained this pure air, not only by moiſtening minium and flowers of zinc with nitrous acid, but alſo by treating all other *metallic earths* in the ſame manner; and he obſerved, that while theſe metallic and earthy matters contained any phlogiſton, the gas obtained was chiefly nitrous, but that by continuing or repeating the proceſs with more ſpirit of nitre, after the phlogiſtic matter had been expelled, pure air was copiouſly produced. The metals themſelves, treated with nitrous acid, yielded, during their ſolution, nitrous gas, and afterwards pure air. When chalk, magneſia alba, wood aſhes, or any of thoſe ſubſtances are uſed, which contain calcareous gas, this gas muſt be previouſly expelled by the acid. And when any earth has been dephlogiſticated and deprived of its gas, it may be uſed repeatedly, as long as it laſts, for the production of this air, by moiſtening it again and again with nitrous acid.

The *denſity* of this pure air was found by Dr. *Prieſtley* to be to that of atmoſpherical air, as 187 to 165. *Vol. II.* 94.

29. Pure air may be obtained from *nitre* alone by expoſing it to violent heat in a gun-barrel. *Exper. and Obſer. Vol. I.* 155.

30. A conſiderable quantity of pure air is extricated in the proceſs for diſtilling acid of nitre from a mixture of nitre and vitriolic acid, or from a mixture of nitre and calcined martial vitriol. Theſe operations muſt be performed in glaſs veſſels, for if iron veſſels are uſed, as is done by the diſtillers of aqua-fortis, nitrous gas is chiefly produced. From an ounce of pure nitre mixed with half an ounce of pure concentrated vitriolic acid, expoſed to heat in glaſs veſſels, I obtained, beſides the uſual quantity of nitrous acid, thirty ounce meaſures of pure air, after making proper allowances for the air previouſly contained in the apparatus. It did not appear that this air was mixed with either nitrous or calcareous gas.

From one ounce of nitre mixed with one ounce of calcined martial vitriol, I obtained 21 ounce meaſures of pure air, beſides the uſual quantity of nitrous acid.

But in the proceſs for obtaining by diſtillation nitrous acid, with arſenic, according to *Stahl*'s method, the whole quantity of the elaſtic fluid produced was nitrous gas. From one ounce of nitre mixed with 15 pennyweights of arſenic, I obtained, beſides the nitrous acid, ſixty ounce meaſures of nitrous gas.

31. Pure factitious air is obtained not only from the nitrous acid mixed with earthy and metallic ſubſtances, but alſo from compounds containing the *vitriolic acid.* Dr. *Prieſtley* obtained air from *alum* expoſed to heat in a gun barrel. (*See Vol. I. p.* 155. And *Signor Landriani* has lately diſcovered that pure factitious air may be obtained by applying heat to *turbith mineral*, as Dr. *Prieſtley* has acquainted me. This experiment Dr. *Prieſtley* has not only verified, but he has alſo found that pure air may be obtained from other combinations of vitriolic acid with metallic ſubſtances, as from *vitriols* of *iron*, *copper*, and *zinc*.

32. Several *mineral ſubſtances* contain pure air, as Dr. *Prieſtley* has lately diſcovered. Among theſe ſubſtances are *Lapis calaminaris*, *Manganeſe*, and *Wolfram*. The relation of theſe diſcoveries cannot fail of making an intereſting part in his fourth volume of *experiments and obſervations*. That a ſmall quantity of air may be obtained from *ſedative ſalt*, he has mentioned in *Vol. II. p.* 86.

C H A P. III.

Of calcareous Gas.

33. FROM various ſubſtances hereafter mentioned a permanently elaſtic fluid may be obtained, whoſe diſtinguiſhing property is, that it is capable of uniting with the cauſtic calcareous earth or quicklime diſſolved in water, and of precipitating this earth from the water. Accordingly when a ſufficient quantity of it comes in contact with lime-water, the water is rendered of an opake white colour, and the ſmall particles of earth which produce this

turbid appearance, gradually ſink to the bottom of the veſſel, leaving the water clear, and free from the earth which had been diſſolved in it; while the earth thus ſeparated from the water which had diſſolved it, is found to have recovered its ſolid form, and remains united and combined with the gas. Whatever gas therefore is obſerved to have this property of combining with the calcareous earth diſſolved in water, may be diſtinguiſhed from other elaſtic fluids by the name of *calcareous Gas*. Dr. *Hales* and his ſucceſſors have denominated this fluid, *fixed Air*; the impropriety of which term appears from conſidering, firſt, that this fluid is *fixed* only when it is combined with the calcareous earth or other ſubſtance; and that it is the reverſe of being fixed, that is to ſay, it is permanently elaſtic, whenever it is diſengaged; and ſecondly, that it does not poſſeſs the diſtinguiſhing properties of the fluid to which the word *air* has been immemorially aſſigned. Mr. *Bergman* of *Upſal* has given to this fluid the appellation of *Aerial acid*, which ſeems to imply that it is the acid conſtituent part of air, which doctrine has not been proved. It is called the *Mephitic acid*, by Mr. *Bewley*; and the *Mephytic gas* by Mr. *Macquer*, who at the ſame time acknowledges that this name is not ſufficiently characteriſtic. Neither of theſe appellations diſtinguiſh it from other gaſes, all which (excepting air) are mephytic or noxious to breathing animals, and ſeveral of which are equally or better entitled to the epithet *acid*, as *vitriolic acid gas*, *marine acid gas*, &c.

34. Calcareous gas may be obtained from a great variety of ſubſtances and by different proceſſes.

It may be extricated by *heat*, or by *acids* from all thoſe earths that are called *calcareous*, that is, all thoſe which by calcination may be converted into quicklime; ſuch as *chalk*, *marble*, *lime-ſtone*, and *marine ſhells*; likewiſe from *fixed* and *volatile alkalies*; and from *magneſia alba*. Thus, if any of theſe ſubſtances be expoſed to violent heat in a diſtilling apparatus of earthen or iron veſſels, the gas that is extricated may be collected; or if acids be added to any of them, an effervescence immediately ariſes, which effervescence proceeds from a number of ſmall bubbles of this gas that are expelled from theſe ſubſtances during their ſolution by the acids. If this effervescence be made in the apparatus repreſented in Fig. 1. C or E, the gas will paſs into and be collected in the jars B or F.

The *quantity* of gas obtained from the above ſubſtances was found to be as follow:

108 grains of *crabs eyes* diſſolved in one ounce and a half of diſtilled vinegar produced in vacuo 81 cubic inches of gas. *Boerhaave.*

One dram of *chalk* diſſolved in two ounces of diſtilled vinegar produced 151 inches of gas in vacuo. *Boerhaave.*

Two drams of *crabs eyes* with one ounce of vinegar produced 12 cubic inches of gas. *Eller*, *Berlin Mem.*

Two drams of *crabs eyes* with one ounce of ſpirit of ſalt produced 75 cubic inches of gas. *Eller.*

Two drams of *red coral* with one ounce of ſpirit of ſalt produced 52 cubic inches of gas. *Eller.*

Magneſia contains half its weight of gas. *Black*, *Edinburgh Eſſays.*

Marble contains $\frac{407}{1000}$ parts of its weight of gas. *Cavendiſh*, *Phil. Tranſ.* 1776.

Lime-ſtone contains $\frac{13}{32}$ of its weight of gas, and $\frac{2}{32}$ of water. *Jacquin*, *Examen Doctrinæ Meyerianæ.*

Cremor calcis contains $\frac{13}{32}$ of its weight of gas. *Jacquin, ibid.*‡

Chalk dried with the heat of boiling mercury contains $\frac{443}{1404}$ of its weight of gas. *Lavoiſier, Opuſc. Phyſ. tom. I.*

One dram of *ſalt of tartar* with half an ounce of ſpirit of nitre yielded 48 cubic inches of gas. *Eller.*

Cryſtals of ſalt of tartar yielded $\frac{428}{1000}$ of their weight of gas. *Cavendiſh.*

Cryſtals of ſoda yielded $\frac{576}{3615}$ of their weight of gas. *Lavoiſier.*

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‡ The *cremor calcis*, or *cream of lime*, is the cruſt formed on the ſurface of lime-water expoſed to the atmoſphere, which cruſt falls to the bottom of the veſſel, and a new cruſt is daily formed, till the whole of the quicklime diſſolved in the water is precipitated. This cruſt is formed by the particles of calcareous gas which float in the atmoſphere, uniting with the particles of quicklime at the ſurface of the lime-water. The earth thus combined with gas is reſtored to the ſame ſtate in which it was before calcination, that is, of mild calcareous earth, which not being ſo ſoluble in water as quicklime is, cryſtallizes on the ſurface of the water; and this cryſtallized calcareous earth, or cream of lime, being heavier than the water, falls to the bottom; while new particles of the quicklime diſſolved in the water, come into contact with the particles of gas floating in the atmoſphere; and the proceſs is repeated, till no more lime remains uncombined with gas in the water. But if the lime-water be expoſed to evaporation, not only this mild calcareous cruſt will be formed in the manner abovementioned, but alſo ſome of the quicklime, being deprived, by evaporation, of the water neceſſary to keep it diſſolved, will be precipitated, and will mix with the cream of lime. Accordingly, M. *Bucquet* obſerved, that the powder precipitated from lime-water poſſeſſed the properties of quicklime. For when he diſtilled a mixture of this powder and ſal ammoniac, he obtained *cauſtic* volatile alkali; whereas, if the powder had conſiſted entirely of the proper cream of lime, ſuch as Mr. *Jacquin* had ſubjected to experiment, according to the above text, he would have obtained a mild volatile alkali.

Volatile ſal ammoniac yielded $\frac{528}{1000}$ of its weight of gas. *Cavendiſh.*

Volatile ſal ammoniac yielded $\frac{768}{1620}$ of its weight of gas. *Lavoiſier.*

35. This gas eſcapes abundantly from the juices of *fruits*, infuſion of *grains*, and of other *vegetable matters*, while they undergo the *vinous fermentation.*

The *quantity* of gas expelled from fermenting ſubſtances was firſt attempted to be aſcertained by Dr. *Hales.* From 42 cubic inches of beer, 639 cubic inches of gas eſcaped in ſeven days; and from 26 cubic inches of bruiſed apples, 968 cubic inches of gas were produced in 13 days. (*Hales's Analyſis.*) Mr. *Cavendiſh* found, that $\frac{57}{100}$ parts of dry ſugar were converted into gas by the vinous fermentation; and that the quantity produced from the fermenting juice of apples was equal to $\frac{381}{1000}$ parts of the dried juice.

Dr. *Prieſtley* tried how much gas could be extracted from different kinds of wines. From one ounce and a half of each of the undermentioned wines, he obtained the following quantities of gas.

Madeira - - - -	$\frac{1}{100}$	of an ounce meaſure.
Port, ſix years old -	$\frac{1}{48}$	ditto.
Hock, five years old -	$\frac{1}{24}$	ditto.
Barrelled claret - -	$\frac{1}{12}$	ditto.
Tokay, 16 years old -	$\frac{1}{20}$	ditto.
Champagne, two years old,	2	ditto.
Bottled Cyder, 12 years old,	$3\frac{1}{4}$	ditto.

Experiments and Obſervations, II. 227.

Much elaſtic fluid eſcapes from liquors undergoing the *acetous fermentatiou.* But whether this gas has the properties of calcareous gas, cannot be ſaid with certainty, as they have not been hitherto examined.

36. Calcareous gas is expelled from *animal* and *vegetable ſubſtances* undergoing the *putrefactive fermentation*. (See Chapter XI.)

37. This gas may be extracted from *animal* and *vegetable* matters by means of *heat*. (See Chap. XII.)

38. This gas is found in *mines*, and other *ſubterraneous* places, (*ſee Chap. XIII.*) and in many *waters*, eſpecially thoſe called *mineral*. (See Chap. XIV.)

39. This gas may be expelled from ſeveral *mineral ſubſtances* by heat. Thus, M. *Krenger* obtained, by diſtilling a *greeniſh fuſible ſpar*, that was luminous in the dark, a gas which united with and cryſtallized a ſolution of fixed alkali, which effects are produced by calcareous gas, as will be ſhewn. Alſo, Mr. *Woulfe* expelled the ſame gas by adding vitriolic acid to *ſpathoſe white ore of iron*, to *Somerſetſhire manganeſe*, and to *Somerſetſhire white-lead ore*. (Philoſoph. Tranſact. vol. LXVI.)

40. Dr. *Prieſtley* has obtained this gas from ſeveral *ſaline* ſubſtances by means of heat, as from *green*, *blue* and *white vitriols*, *calcined alum*, *vitriolated tartar*, *borax*, and *white lead*. (Exper. and Obſerv. II. 112, &c.)

41. This gas is produced in the *revival of metallic calxes* by addition of *inflammable matter*, or by the *electric ſpark*. (Exper. and Obſerv. vol. II. 192.) From 144 grains of minium reduced by means of twelve grains of charcoal previouſly well burnt in a cloſe veſſel, M. *Lavoiſier* obtained, by expoſing the mixture to the focus of a lens, fourteen cubic inches of gas. (*Opuſc. Phyſ. I.* 258.)

42. This gas is produced during the *combuſtion* of every inflammable ſubſtance, excepting *ſulphur* and *metals*. See §. 11.

43. This gas is produced by making *electric ſparks* paſs through air. For if this experiment be made in a glaſs tube, the mouth of which is inverted and immerſed in lime-water, this liquor will be thereby rendered turbid. *Exper. and Obſerv. vol. I.* 186. *See alſo* §. 17. *n.*

44. Small portions of this gas are produced in the ſeveral *proceſſes for obtaining factitious* air. *See* §. 26, 27, 28.

45. This gas is produced abundantly from *nitre* deflagrated with any animal or vegetable inflammable matter. From one pennyweight of nitre and a pennyweight of powdered charcoal, mixed well with two ounces of clean ſand, to prevent the too haſty deflagration, and expoſed to heat in the retort, (*Fig.* 1. E.) I obtained 16 ounce meaſures of calcareous gas.

46. The *ſpecific gravity* of this gas was found by the Hon. Mr. *Cavendiſh*, to be to that of water as 1 to 511; or to that of air when this is 800 times lighter than water, as 157 to 100. According to Mr. *Lavoiſier*, the ſpecific gravity of this gas is to that of air as 561 to 455.

47. The *properties* of *calcareous earths* and of *alkalies are very much altered* by combination with this gas. For when *limeſtone* or other calcareous earths are, by calcination or otherwiſe, deprived of the gas uſually combined with them in their natural ſtate, they are thereby converted into *quicklime*. Alſo when *alkalies fixed* or *volatile* are deprived of their gas, by any means, they are thereby rendered more cauſtic, incapable of effervescing with acids and of cryſtallization, and

more powerfully ſolvent, as Dr. *Black* has proved by accurate and adequate experiments. *Edinb. Eſſays.*

The ſame excellent chemiſt has alſo ſhewn, that by recombining this gas with quicklime, magneſia, or alkalies, which had been previouſly deprived of it, their former weight and properties might be reſtored. From the greater acrimony communicated to quicklime and to alkalies, by depriving them of their contained gas, he has diſtinguiſhed them when thus deprived, or uncombined with gas, by the epithet *cauſtic*, as *cauſtic calcareous earth*, or *cauſtic fixed alkali*, or *cauſtic volatile alkali*; and when theſe earths or alkalies are combined with gas, he calls them *mild*.

Dr. *Black* contrived an apparatus, by which the gas extricated from an effervefcing mixture could be conveyed into a cauſtic alkaline liquor, and ſhewed that by this method, the cauſtic alkali could be rendered mild, and could recover its effervefcing and cryſtallizing properties. His apparatus conſiſted of two phials communicating by means of a bent tube, one end of which is inſerted into the mouth of one phial, and the other end into the mouth of the other phial. In one of the phials he put ſome cauſtic ſpirit of ſal ammoniac, and into the other phial he put ſome mild alkali or mild calcareous earth. Upon this mild alkali or earth he poured through a hole, purpoſely made in the ſide of the phial, ſome acid liquor, which immediately produced an effervefcence as uſual, that is, it extricated from the alkali or earth their contained gas. The gas being thus diſengaged paſſed through the bent tube into the phial containing the ſpirit of ſal ammoniac, with which it combined, and which it changed from a cauſtic to a mild ſtate. For the ſpirit is by this proceſs rendered capable of effervefcing with acids, and if it be much concentrated, it will be ſeen to cryſtallize during its impregnation with gas.

Dr. *Macbride* employed a ſimilar apparatus to impregnate lime-water with gas, by which means he changed the cauſtic earth or quicklime which was diſſolved in the water to a mild calcareous earth, which not being ſoluble in water as quicklime is, was therefore precipitated. *See Macbride on the diſſolvent power of Quicklime.*

48. Dr. *Black* has further determined by experiments the relative powers of the ſeveral alkaline ſubſtances to unite with this elaſtic fluid, or the *affinities* of this fluid towards theſe ſubſtances. He found that this gas was more diſpoſed to unite with *cauſtic calcareous earth* or *quicklime* than with any other ſubſtance; next with *fixed alkali*; then with *magneſia*, and laſtly with *volatile alkali.*

Conſequently mild volatile alkali may be deprived of its gas, or rendered cauſtic, by applying to it magneſia previouſly deprived of its gas, or cauſtic fixed alkali, or quicklime; and at the ſame time the magneſia, fixed alkali, or quicklime, are thereby rendered mild. Magneſia alſo may be deprived of its gas by means of cauſtic fixed alkali, or of quicklime; and laſtly, mild fixed alkali may be rendered cauſtic by means of quicklime, which is at the ſame time rendered mild. Hence ſoap-boilers, in order to increaſe the activity or diſſolving power of their alkali, boil it in water with quicklime.

According then to this doctrine, the *cauſticity* and other *peculiar properties* of *quicklime* and cauſtic *alkalies*, are the *original properties* of theſe ſubſtances, while they are *pure* and *uncombined*; and are not communicated to them by any ſuppoſed abſorption of matter from the fire in calcination, as *Meyer* and other chemiſts maintain *.

49. This gas is capable of adhering to, or combining with, *metallic precipitates.* Thus when a mild alkali or calcareous earth is added to a ſolution of a metal in an acid, the alkali or earth unites with the acid, the metal is precipitated, and the gas of the alkali or earth, which would have occaſioned an efferveſcence if the acid had not been united with a metal, does not in this caſe produce any efferveſcence, but unites with, and increaſes the weight of, the metallic precipitate. Dr. *Black*, who firſt obſerved the union of this fluid with metallic precipitates, attributes the fulminating property of *aurum fulminans* to the gas which adheres to the gold precipitated by a mild alkali. The adheſion of gas to metallic precipitates, is confirmed by M. *Lavoiſier*.

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* This theory, which has been ably inveſtigated, has thrown much light on many chemical phenomena. But although it is well ſupported by the deciſive experiments related by Dr. *Black*, (*Edinburgh Eſſays*,) it has nevertheleſs met with much oppoſition from ſome German and French chemiſts, who adopt the theory of M. *Meyer*, concerning the principle which he called *Acidum pingue*, of which an account is given in the Dictionary of Chemiſtry. *See* ACIDUM PINGUE. On the other ſide, Dr. *Black*'s doctrine has been ably ſupported and confirmed by M. *Jacquin*, in a treatiſe called *Examen chemicum Doctrinæ Meyerianæ de Acido pingui et Blackianæ de aere fixo.* And this treatiſe has been attacked by M. *Crantz*, in his *Rectificatio Examinis chemici Doctrinæ Meyerianæ*, &c.

As not only the reaſonings but alſo the facts related by theſe authors were contradictory, M. *Lavoiſier*, of the Academy of Sciences at Paris, undertook a ſeries of Experiments, with a view of aſcertaining the ſeveral queſtions in diſpute; an account of which he has publiſhed under the title of *Opuſcules phyſiques & chymiques, vol. I.* Theſe experiments, which ſeem to have been made with accuracy and ability, can leave no doubt of the validity of Dr. *Black*'s experiments and deductions.

The precipitation of ſome metallic ſolutions ſeems therefore to be effected by what chemiſts call a double affinity; that is, the gas of the alkali unites with the precipitated metal, while the acid unites with the alkali. Accordingly, the precipitation of ſome of theſe metals requires that the precipitating alkali be mild, that is united with gas. Thus, ſilver diſſolved in nitrous acid cannot be precipitated by a cauſtic volatile alkali, although it may very perfectly by a mild volatile alkali.

This gas not only aſſiſts the precipitation of metals from their acid menſtruums, when it is combined with alkalies, but even ſometimes effects this precipitation, without the aid of an alkali. At leaſt, there is one inſtance of ſuch precipitation, when this gas is added to a ſolution of ſugar of lead, as Mr. *Hey* of *Leeds* has obſerved. *See Appendix to Dr. Prieſtley's firſt volume of Obſervations and Experiments.*

50. This gas is capable of being *abſorbed by water*, and the water thus impregnated precipitates the lime from lime-water, as Dr. *Macbride* has ſhewn.

The quantity of gas which water at the temperature of 55° of *Fahrenheit*'s ſcale can abſorb, was found by Mr. *Cavendiſh* to be more than equal to the bulk of the liquid, and to be greateſt when the water was cold, and compreſſed by an heavy atmoſphere.

The water thus impregnated acquires a *ſubacid taſte*, like that of the mineral waters called *acidulous*, and it alſo acquires a *greater denſity*; the ſpecific gravity of diſtilled water impregnated with gas being to that of diſtilled water not impregnated, as 1000322 to 1000000, according to an experiment made by M. *Lavoiſier*, *Opuſc. Phyſ. & Chym. tom. I. p.* 210.

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Gas abſorbed by water may be thence expelled, by removing the preſſure of the atmoſphere from its ſurface by means of an air-pump; or by boiling the water, or by freezing the water. The greateſt part of the gas eſcapes merely by expoſure to the open air, eſpecially in warm weather.

51. This gas is alſo capable of being abſorbed by other liquors, as by *expreſſed oils* and by *ſpirit of wine*, which laſt liquor is found to be capable of abſorbing 2¼ times its bulk of gas, when expoſed to 46° of heat, according to *Fahrenheit*'s ſcale. *Mr. Cavendiſh*, *Phil. Tranſ.* 1766.

52. This gas *extinguiſhes flame*; and even a mixture of nine parts of air with one part of this gas does not admit a candle to burn, as Mr. *Cavendiſh* has obſerved, *Phil. Tranſ.* 1766.

53. This gas when reſpired is *fatal to animals.* Dr. *Prieſtley* however remarks, that inſects and animals which breathe very little are ſtifled in this fluid, but are not ſoon killed; that butterflies and other flies generally become torpid and ſeemingly dead after being held a few minutes over a fermenting liquor; but revive on being brought into freſh air. *Exper. and Obſerv. vol. I. p.* 36. *Fiſhes* were killed by being put into water impregnated with this gas, *Id. vol. II. p.* 132. This gas is alſo fatal to *vegetable life*. Dr. *Prieſtley* obſerved that ſprigs of mint growing in water were frequently killed in a day, or leſs, by being placed over a fermenting liquor. *Vol. I, p.* 36.

54. This gas *reſiſts putrefaction*, as Dr. *Macbride* has proved from experiments. He ſhews, that by applying this gas to putrefying ſubſtances, their putrefaction is impeded; and he even pretends that they are hereby reſtored from a putreſcent to a ſound ſtate.

He ſupports the opinion of Dr. *Hales*, that gas is the cementing principle of the particles of the ſolids and fluids in which it is contained, and that therefore when this is expelled, by fermentation, putrefaction, or otherwiſe, the coheſion of theſe particles muſt be diſſolved; and when it is reſtored, they may thereby recover their original conſtitution. But why is this gas conſidered as the cement or connective inſtrument more than any of the other principles which enter into the compoſition of theſe bodies? For by depriving a body of any of its conſtituent parts, the coheſion of the whole muſt be diſſolved, whether the principle thus taken away be gas, or earth, or acid, or alkali.

55. This gas when united with water is capable of *acting upon and diſſolving calcareous earth, magneſia, iron*, and perhaps ſome other metals. Mr. *Cavendiſh* firſt obſerved its property of diſſolving calcareous earths, and that although it at firſt precipitates the earth from lime-water, yet it afterwards re-diſſolves this earth. He has alſo ſhewn that the calcareous earth contained in *Rathbone-place* waters is kept diſſolved by no other menſtruum than this gas*. The ſame fluid is probably the ſolvent of the calcareous earth contained in all thoſe waters which depoſite their earthy ſediment upon expoſure to air.

Mr. *Lane* diſcovered that diſtilled water impregnated with the gas of fermenting or effervescing ſubſtances was capable of diſſolving iron, and that the water thus impregnated with the gas and iron had a vinous ſmell and taſte, like thoſe of ſome chalybeate waters, in many of which he thinks the iron is diſſolved merely by means of gas. Hence a mild and pleaſant chalybeate water may be made, by putting filings of iron in water impregnated with the gas obtained from fermenting and efferveſcing ſubſtances. Not only iron in its metallic ſtate, but alſo ſome of the *calciform ores of iron* may be diſſolved in water impregnated with gas, as Mr. *Rouelle* found by experiment. *Lavoiſier*, *Opuſcules*, *I. p.* 156.

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* Phil. Tranſ. 1766, 1767.

This gas occaſions a *precipitation* in a ſolution of *ſugar of lead*, as Mr. *Hey* of *Leeds* obſerves. (*Appendix to Dr. Prieſtley's firſt volume.*) This precipitate may be rediſſolved by adding nitrous acid.

56. The gas obtained from calcareous and alkaline ſubſtances, ſeems to ſuffer a decompoſition when expoſed to water. For, Mr. *Cavendiſh* obſerved, that ſome parts of it were much more eaſily abſorbed than the reſt; and that the reſiduum, which was about one fiftieth or one thirtieth part of the whole quantity, could not be more readily abſorbed by water than air can. And Dr. *Prieſtley* found that the reſiduum which could not be abſorbed by water had ſome of the properties of air, namely, that it efferveſced with nitrous gas, (which is a teſt of air, as ſhall be hereafter ſhewn) and that it was not noxious to a mouſe, although it was not ſo pure that a candle could burn in it. *See* §. 25, *and a note ſubjoined.*

57. Several circumſtances concerning this gas lead to an opinion that it is of an *acid nature*, or that an acid enters into and predominates in its compoſition. Like other acids, it unites with alkalies, diminiſhes their cauſticity, and effects their cryſtallization. It diſſolves calcareous earth and metallic ſubſtances, as iron and zinc. It has alſo been obſerved by Dr. *Bergman*, to alter the blue colour of the juice of tourneſol to red. And laſtly, it communicates an acidulous taſte to water ‡.

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‡ M. *Macquer* is inclined to believe that ſeveral of the ſingular effects, commonly attributed to air, eſpecially thoſe on the colours of

Calcareous gas has been diſcovered to poſſeſs conſiderable *medicinal* powers. Concerning its effects in the *ſcurvy*, and other *putrid* diſeaſes, the *phthiſis pulmonalis*, *ulcers*, *cancers*, and the *ſtone in the bladder*, ſee ſeveral valuable papers in the appendix to Dr. *Prieſtley's Experiments and Obſervations*; the writings of Dr. *Macbride*, Dr. *Percival*, and other late medical authors.

57*. Among the many extraordinary diſcoveries that have been lately made concerning the permanently elaſtic fluids, is that of Mr. *Achard* of *Bale*, who is ſaid to have made true *cryſtals*, as hard and of the ſame ſhape as the native rock-cryſtals, by applying calcareous gas in a certain manner, and by a very ſlow operation, to ſome earthy matter.

CHAP. IV.

On inflammable Gaſes.

58. SOME gaſes are found to be capable of being inflamed. Theſe are procured from very different matters, and by very different methods.

59. An inflammable gas is frequently found in *mines*, eſpecially *coal-mines*, which ſometimes takes fire, and explodes with great danger to the miners. *See Chap. XIII.*

60. Dr. *Hales* obtained an inflammable gas by diſtilling

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o bodies, are cauſed by the calcareous gas, ſome portion of which, greater or ſmaller, is always mixed with the atmoſphere. Such are, the blackneſs which black dyes acquire by expoſure to air, the change of the green colour of a vat of indigo to a blue, the redneſs given to the liquor of the *murex*, the violet colour reſtored to the tincture of *orſeille*, the weakening of many colours, bleaching, and other effects of expoſing coloured bodies to the atmoſphere. He thinks that light alſo may contribute to produce theſe ſingular effects. But he obſerves, that this ſubject is little underſtood, and he propoſes to inveſtigate it by further experiments.

ſtilling *wax*, *pitch*, *oyſter-ſhells*, *peaſe*, *amber*, and *coals. See Chap. XII.* Probably it might be obtained by applying heat ſuddenly to any *dry inflammable matter*, without excepting even the *inflammable* or *calcined metals.* Dr. *Prieſtley* procured inflammable gaſes from clean filings of *iron*, *zinc*, *braſs*, and *tin*, by expoſing theſe ſeparately to the focus of a burning lens in vacuo; and likewiſe from *iron filings* and *chalk*. *Vol. II. p.* 107, &c. But he could not procure any inflammable gas from *biſmuth*, *regulus of antimony*, *nickel*, *lead*, or *copper*; nor from *metallic calxes*.

61. An inflammable gas may be produced by diſſolving *iron*, *zinc* or *tin* in the *diluted vitriolic*, or *marine acids*.

According to experiments made by Mr. *Cavendiſh*, one ounce of zinc diſſolving in either of the above acids produced a quantity of inflammable gas equal in bulk to 356 ounces of water; one ounce of iron diſſolving in ſpirit of vitriol produced a quantity of gas equal in bulk to 412 ounces of water; and an ounce of tin produced as much gas as occupied the ſpace of 202 ounces of water. Dr. *Prieſtley* has produced an inflammable gas by diſſolving zinc and iron in radical vinegar; and by diſſolving copper, lead, and regulus of antimony in ſpirit of ſalt. *Vol. III. p.* 255, 256. The water over which this gas is contained becomes covered with a thin film, which is red, like ochre, if the gas has been procured from iron, and is white, if from zinc. *Vol. I.* 58.

62. *Marine acid gas*, (deſcribed in chap. VII.) or, the vapour of concentrated marine acid, may be *changed into an inflammable gas* by acting upon inflammable ſubſtances, as *ſpirit of wine*, *oil of olives*, *oil of turpentine*, *charcoal*, *phoſphorus*, *ſulphur*; and alſo upon *dry cork*,

cork, *oak*, *ivory*, *beef*, and even *flint*. (*Exp. and Obſer- vol. I.* 149 *and* 232.) This marine acid gas being expoſed to *quicklime* till $\frac{13}{14}$ were abſorbed, the remainder was obſerved to be inflammable. *Id. vol. I. p.* 236.

63. An inflammable gas eſcapes from *putreſying animal or vegetable matters*. The waters of ſome *rivers* into which much fermentable matter is waſhed, as of the *Thames* and the *Aluta*, after having been confined during a certain time in caſks, emit an inflammable gas. The ſurfaces of rivers are ſometimes covered with an inflammable gas or vapour. *Exp. and Obſerv. vol. I. Appendix.* Inflammable vapours riſe frequently from churchyards, houſes of office, or from whatever places in which putreſcent animal matters are collected.

Of the quantity of this gas which may be obtained from given quantities of putreſying matter, ſee Chap. XI.

64 An inflammable gas exhales from *liver of ſulphur*, upon adding an acid, as *Meyer* and *Rouelle* have obſerved. (*Lavoiſier, Opuſc. Phyſ. tom. I.* 161.) The gas which is diſcharged from mixtures of ſulphur with filings of iron, or zinc, is alſo found to be inflammable. *See Exp. and Obſerv. vol.* III. *p.* 259.

65. *Cygna* obſerves, that *air ſaturated with volatile alkali* is inflammable: and Dr. *Prieſtley* found, that *alkaline gas* was alſo inflammable.

66. Dr. *Prieſtley* obſerved, that the *electric ſpark* taken in oil, ether, ſpirit of wine, or ſpirit of ſal ammoniac, produced an inflammable gas. *Exp. and Obſerv. vol.* I. 242. 245.

67. M. *de Laſſone* has obtained inflammable gaſes by diſſolving *zinc* and *iron* in *alkalies*. He diſcovered that liquid *volatile alkali* is capable of diſſolving filings of

zinc, and that, during the ſolution (which requires very little heat) an inflammable gas, capable of fulminating, when mixed with air, is expelled from the mixture, and may be collected by means of a proper apparatus.

He has alſo obtained a ſimilar gas from the ſolution of filings of zinc by *cauſtic fixed mineral alkali*, which was applied to the zinc in a liquid ſtate, and was aſſiſted by a boiling heat.

Filings of *iron*, although leſs ſoluble than thoſe of zinc, by theſe alkalies, did nevertheleſs yield a gas no leſs inflammable and detonating than the preceding. M. *de Laſſone* could not diſſolve either of theſe metals by means of a mild fixed alkali. He obſerved however, during the boiling of this alkali in a liquid ſtate with filings of theſe metals, that an elaſtic fluid was produced, which was found (he ſays) to be common air.

The ſolution of zinc, and of its flowers, by mild volatile alkali, produced ammonical ſilky ſalts, from which M. *de Laſſone* obtained, by means of heat, a gas which was not inflammable, but poſſeſſed the properties of calcareous gas.

68. As *ether* has the ſingular property of mixing with any permanently elaſtic fluid, and expanding along with it; if therefore air be ſaturated with ether, an inflammable gas will be thereby formed. The eſſential oil or ſpiritus rector of *fraxinella* ſeems to have a ſimilar property of forming an inflammable compound, by mixing with air. For when this plant is in flower, the vapour which exhales from it may be kindled by a lighted candle.

69. Dr. *Prieſtley* has ſhewn, that an inflammable gas, which burns with a blue flame, may be obtained

from the nitrous acid, acting upon *ſpirit of wine* or other inflammable ſubſtances, and that this gas is produced (together with the nitrous gas deſcribed in chap. V.) during the action of that acid upon *metals*, eſpecially upon *zinc* and *tin*. He obſerved this inflammable gas alſo in the diſtillation of a ſolution of zinc in nitrous acid, in the period between the production of phlogiſticated, and that of the pure factitious air deſcribed in §. 28. *Experiments and Obſervations, vol. III. p.* 24.

70. An inflammable vapour or gas was produced by repeatedly diſtilling the ſame *nitrous acid* from *quicklime*. Pott *on the ſolution of quicklime by nitrous acid*.

71. The inflammability of this was obſerved to be *greateſt*, when the *diſtillation* of inflammable matter was *haſtily performed*, and with a *heat ſuddenly raiſed*; or when the *ſolution of metals* in acids proceeded with the *greateſt vehemence*, as when heat was applied, and acids of a proper ſtrength were employed; and when the *putrefaction* of animal and vegetable matters were *haſtily excited*. Exp. and Obſ. I. 58.

72. The *ſpecific gravity* of inflammable gas was found by Mr. *Cavendiſh* to be eleven times leſs than that of common air, when this is 800 times lighter than water.

73. The *mixture of air* is neceſſary to the inflammation of this gas, as of other inflammable ſubſtances. Mr. *Cavendiſh* has made experiments to diſcover the effects of firing different proportions of air, and the inflammable gas deſcribed in §. 61; and he found the following reſults:

A mixture of nine parts of air with one part of inflammable gas, did not fire eaſily, and the inflammation was accompanied with little ſound.

Two parts of inflammable gas, and eight parts of air, were eaſily fired, and the ſound produced was moderately loud.

Three parts of inflammable gas, and ſeven parts of air, gave a very loud ſound.

Four parts of inflammable gas, and ſix parts of air, gave a ſound very little louder than the former mixture.

Equal parts of gas and air, ſounded like the laſt mixture.

In the firſt experiment, when nine parts of air were mixed with one part of gas, the flame ſpread gradually through the bottle containing the mixture. In the three next experiments, no light could be perceived, perhaps, becauſe the flame laſted too ſhort a time to make a ſufficient impreſſion on the eye. When equal parts of the two fluids were employed, a light was ſeen.

A mixture of ſix parts of inflammable gas, and four parts of air, produced a ſound which was not loud, and after the exploſion it continued to burn a ſhort time.

A mixture of ſeven parts of inflammable gas with three parts of air, gave a gentle bounce, and continued to burn ſome ſeconds.

A mixture of eight parts of inflammable gas with two parts of air, caught fire without noiſe, and continued to burn only in the neck of the bottle.

From theſe experiments Mr. *Cavendiſh* infers, that unleſs the mixture contain more air than inflammable gas, the air is not ſufficient to conſume the whole of the gas, and that the remainder burns by means of air ruſhing into the bottle after the exploſion ‡.

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‡ The phenomena accompanying the inflammation of inflammable gas are well exhibited in the following experiment, related by

74. The *nitrous acid* in this, as in other inſtances, ſeems to ſupply the place of air in aſſiſting the inflammation of this gas, as appears from ſome curious experiments of Dr. *Prieſtley*. ***Experiments and Obſervations**, vol.* III. *p.* 260.

He filled jars with nitrous acid, and inverted the jars ſo that their mouths were immerſed in the ſame acid; he then diſplaced this acid, by throwing inflammable gas into the inverted jars. The gas which

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by Mr. *Warltire. Appendix to Dr. Prieſtley's Exper. and Obſerv. vol. III. p.* 367.

“I have ſeveral times repeated an experiment with inflammable air, that appears to me very curious. I fit a glaſs tube into a tapering cork, and that to a round-bottomed phial, in ſuch a manner that a bend in the tube, when hung over the ſide of a tub, be almoſt two inches under the water, but that the end may riſe four inches higher than the bend. The phial being charged with the proper materials for producing inflammable air briſkly, it muſt be lighted, as it diſcharges from the end of the tube, and will continue a flame as long as any inflammable air riſes, provided care is taken to prevent any moiſture aſcending along with the inflammable air. The phial and its tube being placed on the edge of the tub, a receiver, ſuch as for an air-pump, is to be brought over the burning air, and its edge ſunk in the water upon the bend of the tube. The inflammable air continues to burn as long as there is common air in the receiver capable of ſupporting the flame. The appearances in this experiment are very remarkable. About as much inflammable air vaniſhes as is equal to the bulk of the common air; the burning is attended with much heat and light; the common air is contracted full one fifth part of its original dimenſions; immediately after the flame is extinguiſhed, there appears through almoſt the whole of the receiver, a fine powdery ſubſtance like a whitiſh cloud, and the air in the glaſs is left perfectly noxious. The bent tube ſhould be ſlipped from under the receiver, the inſtant the flame goes out, to prevent the inflammable air mixing with the other air in the receiver.”

had thus paſt through nitrous acid, was found to be more or leſs inflammable, (without mixture of air) and capable of producing an exploſion, more or leſs loud, in proportion to the ſtrength of the acid. He obſerved, that this gas remained inflammable a ſhort time only after it had paſt through the acid; probably becauſe the acid vapour was gradually depoſited; and alſo that the gas loſt its property of inflammability without mixture of air, by making it paſs through water, in which caſe, the acid vapour is probably ſeparated from the gas, by means of the water. *Experiments and Obſervations on Air, vol. III. p.* 260. *and vol. I. p.* 65.

75. The inflammable gaſes, which have been principally obſerved, *explode* during their inflammation, yet many others burn very well without exploſion. Such are the inflammable gaſes extricated from a mixture of calx of zinc and charcoal, and from Pruſſian blue, by expoſing theſe ſubſtances to heat in a gun-barrel, as M. *de Laſſone* has obſerved. The detonation of inflammable gaſes may be prevented, as M. *de Laſſone* affirms, by mixing them with nitrous gas: and Dr. *Prieſtley* obſerves, that if inflammable gas be mixed with nitrous gas, the mixture burns with a green flame. *Exp. and Obſerv. I.* 117.

75.* Inflammable gas may be kindled by the *electric ſpark*, even when the electricity is not very ſtrong, as *Signor Alexander Volta* has obſerved. *Exp. and Obſerv. vol.* III. *Appendix*. M. *Chauſſier* alſo ſhews, that inflammable gas may be kindled by electric ſparks. For this purpoſe he filled a bladder with this gas, and made it paſs from thence into the open air through a tube, at the extremity of which was a hollow copper ball pierced with one or more holes, through which the gas iſſued. By directing the ſpark to one or more of the holes, the gas, which mixed with air as ſoon as it iſſued, was immediately kindled, and continued to burn as long as the inflammable gas was preſſed out of the bladder. When the ball had only one hole, there was a ſtream of flame, like that of an enameller's lamp, by means of which M. *Chauſſier* melted metals, and revived metallic calxes without addition, the phlogiſton of the gas ſerving for the purpoſe of reduction: and he pretends, that metals may be melted with leſs heat, and in leſs time, by means of this flame, than of common fire. When a tapering hollow tube was ſubſtituted to the ball, ſo that the gas was made to iſſue through a ſmall hole in the point of this tube, no inflammation could be made to take place by applying electric ſparks, although the point was thereby rendered luminous. *Rozier's Journal*, *October* 1777.

Signor *Volta* thinks that the *ignes fatui*, which he ſuppoſes to be inflammable gas that has ariſen from marſhy grounds, and alſo that the *falling ſtars* may have been kindled by means of electricity.

75.** Meſſrs. *Macquer* and *De Montigny* have obſerved, that pure inflammable gas obtained from zinc and iron diſſolving in vitriolic acid, being applied to ſolutions of ſilver, mercury, lead, and other metals, communicated immediately to theſe ſolutions, the brown or black colour, which indicates the union of phlogiſton with metallic earths, and an approximation to reduction.

Theſe chemiſts have not aſcertained what change is produced upon the inflammable gas by this ſpecies of decompoſition, but they mean to inveſtigate this matter by further experiments. *Diction. de Chymie. Gas inflammable.*

76. Mr. *Cavendiſh* did *not* find that this gas was *abſorbed by the water*, over the ſurface of which it ſtood: and it certainly may remain thus long without any conſiderable diminution. But Dr. *Prieſtley* ſays, that by agitation in boiled water, no leſs than three fourths of this gas may be abſorbed, and that the remainder was but weakly inflammable. *Vol. I. p.* 67. And the inflammable gas, thus diminiſhed by agitation in water, was found to have ſo far acquired the properties of air, that when it was mixed with nitrous gas, a conſiderable diminution was obſerved. *Id. vol. I.* 188.

77. Inflammable gas is *not diminiſhed* by fumes of *liver of ſulphur*, or by the *electric ſpark*. Neither did the electric ſpark paſſing through this gas change the colour of a ſolution of archil in water. *Exper. and Obſerv. vol. I.* 247. The effects of expoſing this gas to *oil of turpentine* were remarkable. Its bulk was thereby conſiderably enlarged; it was rendered leſs inflammable; and it was made capable of diminiſhing nitrous gas nearly as much as air is. *Id. vol. III. p.* 366.

78. Inflammable gas is *noxious to animals*; but it does *not* ſeem to be *hurtful to vegetable life*; for Dr. *Prieſtley* found that plants grew pretty well ſeveral months in it, and that it ſtill continued inflammable. *Vol. I.* 61.

CHAP. V.

On nitrous Gas.

79. DR. *Hales* obſerved, that when a mixture of nitrous acid with a martial pyrites was diſtilled; or when the nitrous acid was poured upon antimony, or mercury, or filings of ſteel, a gas was produced, which readily *united with air*, and produced *heat* by their union, while the mixture became *red* and *turbid*, and its quantity or *bulk* was found to be conſiderably *leſs* than the ſum of the quantities of the two fluids employed. *Statical Eſſays, vol. I.* 224. *and vol. II.* 280. Notwithſtanding theſe ſingular appearances, no further notice was taken of this gas, till Dr. *Prieſtley* thought it a ſubject worthy of his inveſtigation; and how ſucceſsfully he has proſecuted his inquiry, the following part of this chapter will evince. To this fluid he has given the name of *nitrous Air*.

80. Dr. *Prieſtley* has procured the ſame gas, by diſſolving in the nitrous acid any of the following metals, *iron*, *copper*, *mercury*, *ſilver*, *biſmuth*, and *nickel*, and alſo by diſſolving *gold* or *regulus of antimony* in aqua regia. He obtained little or no gas by diſſolving *lead* in nitrous acid; and he found that the gas produced by diſſolving *zinc* and *tin* in that acid, had the properties of the nitrous gas in a ſmall degree only. *Exper. and Obſerv. vol. I. p.* 110 *and* 126. *and vol. III. p.* 17. M. *de Laſſone* ſays, that the gas which he obtained, by diſſolving zinc in nitrous acid, was not *nitrous*, but *calcareous gas*.

81. Dr. *Prieſtley* has obtained this gas, by applying nitrous acid to almoſt all kinds of inflammable ſubſtances,

ſtances, and more eſpecially to *vegetable* than to *animal* matters. Both theſe matters, thus treated with nitrous acid, yielded alſo conſiderable quantities of calcareous gas; but this difference was remarked between them, that vegetable matters yielded a much larger quantity of nitrous gas, and that the gas obtained from animal matters contained alſo a portion of a gas which is ſimilar in its properties to air in which candles had burnt till they became extinct, and which he therefore calls *phlogiſticated air*. This ſeems to eſtabliſh a new diſtinction between the animal and vegetable kingdoms. *Exp. and Obſerv. vol. II. p.* 145.

82. A large quantity of elaſtic fluid is expelled in the proceſs for making *nitrous ether* by diſtillation; and the *Duc d'Ayen* has found, that this fluid conſiſted of nitrous gas mixed with *ether*, which has the ſingular property of expanding into an elaſtic fluid when mixed with any kind of gas, as Dr. *Prieſtley* has obſerved. *Id. vol. I. p.* 252.

83. The ſingular phenomena which accompany the mixture of this gas with air have been mentioned in §. 79, namely, the *heat*, *redneſs*, *turbid appearance*, and *diminution of bulk*.

Dr. *Prieſtley* obſerves, that the diminution of a mixture of this gas and of common air is not an equal diminution of both the kinds, but (ſays he) " of about " one fifth of the common air and as much of the *nitrous air* as is neceſſary to produce that effect; which, " as I have found by many trials, is about one third " as much as the original quantity of common air. " For if one meaſure of nitrous air be put to two mea- " ſures of common air, in a few minutes (by which " time the efferveſcence will be over, and the mixture " will have recovered its tranſparency) there will want

" about one ninth of the original two meaſures; and " if both the kinds of air be very pure, the diminution will go on very ſlowly, till, in a day or two, " there will remain one fifth leſs than the original " quantity of common air." *Exp. and Obſerv. vol. I. p.* 110.*

When air is once ſaturated with the nitrous gas, any further addition of gas occaſions an equal encreaſe of the bulk of the mixture, and produces no heat or redneſs.

The nitrous gas ſuffers no diminution upon being mixed with any other kind of gas than air, and conſequently the diminution is greater when the air is purer, as Dr. *Prieſtley* has obſerved. And he has accordingly very happily applied this nitrous gas, as a teſt, to *diſtinguiſh* air from other kinds of gas, and to *meaſure the purity of air*; by which means we are furniſhed with a new method of examining air, and conſequently of extending our knowledge of the atmoſpherical fluid.

In order to examine or aſcertain the purity of any kind of air, let a jar Y (*ſee Plate and explanation*) be filled with water, and inverted into a veſſel of water. Into this jar pour two meaſures of the air to be tried, and one meaſure of nitrous gas. If, when the effervеſcence is over, and the mixture has loſt its turbid appearance, the quantity remaining be only one meaſure and ſeven ninths of a meaſure, we may know that the air is as pure at leaſt, as the air appeared to be in the trials made by Dr. *Prieſtley*, from which he deduced the rule above quoted. If the quantity of the remaining mixture be greater than $1\frac{7}{8}$ meaſures, then the air is known to be proportionably leſs pure. But if, upon adding another meaſure of nitrous gas, a further diminution takes place, that is, if the quantity of the remaining mixture be leſs than $2\frac{7}{8}$ meaſures, the air will be known to be purer in proportion to the further diminution that may be produced by adding more nitrous gas. Accordingly, when pure factitious air (§. 26, 27, 28.) is ſubjected to this mode of trial, four, five, or even ſix times the above-mentioned quantity of nitrous gas may be added to this pure air, before any augmentation happens of the bulk of the air employed.

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* M. *Lavoiſier* concludes from his experiments, that the proportion of air and nitrous gas requiſite to produce a ſaturation, is 16 parts of the former to 7½ parts of the latter; and that, when this proportion is obſerved, the whole quantity of nitrous gas diſappears, and alſo one fourth of the air employed.

This mode of trial may be applied to diſcover the ſtate and ſalubrity of air in different places and in different times. *Exper. and Obſervat. vol. I. p.* 116. Accordingly *Signor Landriani*, in a tour he lately made through *Italy*, examined, by this method, the ſtate of the air, with regard to its purity, in the different places through which he paſſed, and he found that the reſult of his experiments correſponded exactly with the opinion which generally prevailed among the inhabitants concerning the ſalubrity of the air. In the mountains near *Piſa*, he found that the air was more and more pure, as he aſcended higher; and that at *Mount Veſuvius*, the air was more vitiated, as it approached the ſummit. The air of the *Pontine lakes*, that of the *Scirocco* at *Rome*, that of the *Campagna Romana*, of the *Grotta dei Cani*, of the *Zolfatara* at *Naples*, of the Baths of Nero at *Baia*, of the ſea-coaſt of *Tuſcany*, were all found, on examination, to be ſuch as daily experience had led him to expect.

84. This gas *extinguiſhes flame*, (Hales, Appendix) and it is *noxious to animals*. But frogs and ſnails were obſerved to live in it a conſiderable time, although they at length died in it. *Exper. and Obſerv. vol. I. p.* 119. 226.

85. This gas is capable of being *abſorbed* by various *liquors*, and in various proportions.

Diſtilled *water abſorbs* about one tenth of its bulk of this gas; and the water thereby acquires an acid taſte, and becomes covered with a film. Nitrous gas* was by long *agitation* in water rendered capable of being *diminiſhed by freſh nitrous gas*, as air is; and when by this agitation it was reduced to one eighteenth of its original bulk, a mouſe could live in it. *Exp. and Obſerv. I.* 189. 120.

Nitrous gas was very ſuddenly and copiouſly *abſorbed* by *ſpirit of nitre*; the colour of which was thereby changed firſt to a deep orange, then to a green. The quantity of gas abſorbed by a ſtrong ſpirit of nitre was in bulk 650 times greater than the quantity of ſpirit employed. Towards the end of the proceſs, the evaporation of the acid ſpirit was obſerved to be ſo very great, that, at laſt, only half the quantity of ſpirit remained, and this was further obſerved to be very weak. The abſorption of the gas ſeems to have rendered the ſpirit very volatile. *Exper. and Obſerv. vol. III.* 122, &c.

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* Mr. *Bewly* remarks, that this gas does not give to water a ſenſible acid impregnation, unleſs it comes into contact, or is mixed with a portion of air. *Exper. and Obſerv. I.* 318. Neither does it ſeem to poſſeſs any of the properties of acids, while it retains its elaſtic ſtate. The *Duke de Chaulnes* introduced ſome tincture of tourneſol into a veſſel containing nitrous gas, and obſerved, that no alteration was produced in the colour of the liquor.

Oil of vitriol was obſerved to abſorb about as much of this gas as water does; and to be thereby rendered of a purple colour. *Id.* III. 129.

Spirit of ſalt imbibed one twentieth of its bulk of this gas, and its colour was thereby changed from yellow to a ſky-blue. *Id.* III. 129.

This gas was alſo abſorbed by concentrated *vegetable acids.* Id. III. 130.

Nitrous gas has been obſerved by Dr. *Prieſtley* to be capable of being abſorbed by *oils*, *ether*, *ſpirit of wine*, and by *cauſtic alkali*. The quantity abſorbed by oil of turpentine was conſiderable, being equal in bulk to eleven times the quantity of oil employed. The whole of a given quantity of gas however could not be thus abſorbed; for a reſiduum, which extinguiſhed a candle and ſeemed to be like air which had been expoſed to burning ſubſtances, remained equal to one fourth of the quantity of gas expoſed to the oil of turpentine. *Exper. and Obſerv. vol. III. p.* 112, &c.

86. Nitrous gas being expoſed to a large ſurface of *iron* during two months, was rendered *capable of maintaining flame*, and even enlarging the flame, although it continued highly noxious. The ſame effects were produced by expoſing nitrous gas to *liver of ſulphur*, during twenty-four hours; (*Exper. and Obſerv. I.* 216, 217. *II.* 178.) and to a mixture of filings of iron and ſulphur. *Id. III.* 141.

A gas, poſſeſſed of this inflammable property, may be procured by diſſolving tin or zinc in nitrous acid. It may alſo be obtained by applying heat to a ſolution of iron in that acid, after the common nitrous gas had eſcaped from it during the ſolution, without heat. *Id. III.* 133, &c.

Nitrous gas was diminiſhed, by expoſure to *iron-filings and ſulphur* made into a paſte with water, to one fourth of its original dimenſions. When it has been thus diminiſhed by iron-filings and ſulphur, the reſiduum cannot be diminiſhed by air, nor by agitation in water. *Id.* I. 223.

87. The *electric ſpark* taken in nitrous gas diminiſhed this gas to about one fourth of its original quantity, and rendered it unfit for diminiſhing air. When this ſpark was taken while the gas was in contact with a ſolution of archil in water, the colour of this ſolution was changed from blue to red, in a very great degree. *Exper. and Obſerv. vol.* I. 122. II. 238.

88. Nitrous gas is quickly decompoſed by a ſolution of *green vitriol* in water; the colour of which is thereby rendered darker, but is reſtored to green, on expoſing the ſolution to air. *Exper. and Obſerv.* III. *Preface, p.* 33.

89. The *denſity* of nitrous gas appeared by an experiment of Dr. *Prieſtley* to be to that of air, as 184 to 185. *Exper. and Obſerv. vol.* II. *p.* 94.

90. Dr. *Prieſtley* thinks that this gas conſiſts of the vapour of the nitrous acid united with phlogiſton, together perhaps with ſome ſmall portion of metallic calx. *Exper. and Obſerv. vol.* I. *p.* 271.

And Mr. *Bewley* juſtly remarks, that this nitrous acid in form of a fluid, not condenſable by cold, cannot be reſtored to a liquid ſtate without the preſence and admixture of air. *Exper. and Obſerv.* I. *Append.* 318.

The red appearance therefore which takes place upon mixing nitrous gas with air, ſeems to proceed from the many ſmall particles or minute drops of nitrous acid juſt reduced from an elaſtic ſtate to that of a liquid, in conſequence of the mixture of this gas with air; and theſe particles gradually ſubſide, or are abſorbed by the water, and diſappear.

CHAP. VI.

On vitriolic acid Gaſ.

91. THE *vitriolic acid* is capable of being raiſed by means of heat, and of mixture with *oils*, *charcoal*, or other *inflammable ſubſtance*, into an elaſtic fluid, which is not condenſable by cold, as Dr. *Prieſtley* has diſcovered. *Exper. and Obſerv. vol. II. p.* 7. This elaſtic fluid is called by Dr. *Prieſtley*, who firſt obſerved it, *Vitriolic acid air*.

92. This gas is very readily *abſorbed by water*; when thus brought into the form of a liquid, it poſſeſſes all the properties of the vitriolic, or rather perhaps of the volatile vitriolic or ſulphureous acid. As this gas ſo readily unites with water, it therefore cannot be collected in veſſels filled with this liquid, but with ſome fluid on which it has no action, as mercury.

93. The ſame kind of gas may alſo be obtained by means of heat from concentrated vitriolic acid and ſeveral *metallic ſubſtances*, as copper, ſilver, lead, iron and zinc. It has been already obſerved, that a gas of a different kind may be obtained from the ſame acid in a dilute ſtate acting upon ſome of theſe metals. *See Chap. IV. on inflammable gas.*

94. The following *properties* of this gas were obſerved by Dr. *Prieſtley*. Exper. and Obſerv. vol. II. p. 7, &c.

a. It was *heavier than air*.

b. It *extinguiſhed flame*.

c. It was *abſorbed by charcoal,* to which it communicated a very pungent ſmell.

d. It *diſſolved camphor* readily, and reduced it to a tranſparent liquor, from which, by addition of water, camphor was reproduced.

e. It did *not act* upon iron, nitre, common ſalt, or ſal ammoniac.

f. It formed a *white cloud* upon being mixed with a vapour of *volatile alkali.*

g. It *injured common air.*

h. When *electric ſparks* were paſſed through this gas, included by means of quickſilver, in a glaſs tube, the ſides of the tube became tinged with a black ſtain *.

CHAP. VII.

On marine acid Gas.

95. CHEMISTS have remarked, that a conſiderable quantity of elaſtic fluid is diſengaged during the diſtillation of ſpirit of ſalt by means of oil of vitriol, by which means much of the ſtrongeſt acid eſcapes; and Mr. *Woulfe,* (Phil. Tranſ. vol. LVII.) in order to prevent this loſs, has invented an apparatus, by means of which the vapour is made to paſs repeatedly through water, and is thereby condenſed; but this fluid was conſidered as a mere vapour, condenſable by cold. Mr. *Cavendiſh* however, in attempting to produce an inflammable gas from marine acid acting on copper, in the ſame manner as he had done

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* The ſame ſtain is produced when the electric ſpark, and more effectually when the electric ſhock is made to paſs through common air confined by quickſilver. This black matter, when heated, appears to be pure quickſilver. *Exp. and Obſer. vol. III. Pref. p.* 34.

from that acid acting on iron and zinc, found that an inflammable gas could not be thus obtained; but from the phenomena accompanying the experiment was led to think, that ſome elaſtic fluid had been formed in the operation, and had been condenſed as ſoon as it had come into contact with water. *Phil. Tranſ. vol. LVI.* This appearance of an elaſtic fluid that was condenſed by contact with water, ſeemed to Dr. *Prieſtley* to be an object worthy of inveſtigation, and from the experiments which he made with this view, he diſcovered a new ſpecies of gaſes; namely, that to which the epithet *acid* is given. He diſcovered that a gas could be obtained not only from ſpirit of ſalt acting upon copper, but alſo from that acid alone by means of heat; that this gas was quickly abſorbed by water, but when collected in jars previouſly filled with quickſilver, that it retained its elaſticity, and was therefore, according to our definition, a true permanent gas; to which he gave the appellation of *marine acid air*. Exper. and Obſerv. vol. I. p. 143.

96. The water which has abſorbed this gas, becomes a *ſpirit of ſalt*, more or leſs ſtrong in proportion to the quantity of gas abſorbed, and thus a ſtronger marine acid ſpirit may be obtained than by any other method. *Exper. and Obſerv. vol. I. p.* 148. *Ice* is as quickly diſſolved by this acid gas, as it is by a hot fire. *Id. vol. I. p.* 240.

97. This gas *acts upon* many *metallic* and *inflammable ſubſtances*, and is thereby changed into an *inflammable gas*, as is ſhewn in chap. IV. §. 62. But the fumes of *liver of ſulphur* did not render it inflammable: theſe fumes reduced its dimenſions to one half. *Exper. and Obſerv. vol. I. p.* 235.

Marine acid gas was a little diminiſhed by the *electric ſpark* paſſing through it. *Exp. and Obſerv. vol. II. p.* 239.

98. This gas *extinguiſhes flame*; and when mixed with air, it gives to flame a beautiful green or bluiſh colour. *Id. I.* 147.

CHAP. VIII.

On nitrous acid Gas.

99. NOT only the nitrous gas above deſcribed (chap. V.) may be obtained from the nitrous acid; but alſo the mere vapour of heated ſpirit of nitre was diſcovered by Dr. *Prieſtley* to aſſume the form of gas: at leaſt, it remained uncondenſed by the cold of the atmoſphere to which it was expoſed. *Exper. and Obſerv. vol. II. p.* 169.

The difficulty of finding a fluid capable of confining this vapour, and on which it has no action, prevented a complete inveſtigation of it: for it was readily abſorbed by water, and it diſſolved quickſilver. Our knowledge of it is therefore very imperfect; but if it ſhould be found, upon further examination, to be a permanent gas, it may be denominated *nitrous acid gas*; while the gas deſcribed in chap. V. may retain the name of *nitrous gas.*

When this vapour was mixed with nitrous gas, the mixture became red and turbid, the nitrous gas was diminiſhed, and its power of diminiſhing air was leſſened. *Exper. and Obſerv.* II. 170.

Dr. *Prieſtley*, to whom we are indebted for every thing we know concerning this gas, not finding any vapour in the ſtate of liquor capable of containing it, made it paſs from the veſſel containing nitrous acid acting upon metals, into phials containing air, by which means the phials were filled with this vapour mixed with air. The vapour in theſe phials was obſerved to be red; and the intenſity of the red colour of this vapour, and alſo of the high-coloured ſpirit of nitre itſelf, was encreaſed by heat. This phenomenon Dr. *Prieſtley* attributes to the action of heat on the phlogiſton contained in the vapour and acid.

This vapour being mixed with air, and afterwards ſeparated from the air by being abſorbed by water, was found to have ſo altered the air, that it was no longer capable of diminiſhing nitrous gas. *Exp. and Obſerv. vol.* III. *p.* 192.

Water very readily abſorbs this vapour, and is thereby converted into a ſpirit of nitre, the colour of which varied according to the ſtrength of the impregnation, from blue to green, and thence to a yellowiſh hue. *Id.* III. 198.

During the beginning of the impregnation of the water with this nitrous acid vapour, the water was obſerved to ſparkle much; and the impregnated water gradually emitted ſo much elaſtic fluid during two or three days after the impregnation, that the veſſels, if cloſely ſtopt, were in danger of burſting. This elaſtic fluid was expelled more copiouſly by heat; and upon examination, was found to be *nitrous gas.* The quantity of this gas which was expelled from impregnated water, was in bulk ten times greater than the water employed. But it appears from Dr. *Prieſtley's* former experiments, that water can abſorb only one tenth of its bulk of nitrous gas; therefore this large quantity of nitrous gas does not enter as nitrous gas mixed with the acid vapour into the water; but ſeems to be formed by the union of the vapour with the water.

This acid vapour, united with expreſſed oils, rendered them of blue and yellow colours, and coagulated them. By combining with eſſential oils, it produced heat and effervеſcence; and once an exploſion happened. *Exper. and Obſerv.* III. 208. 210.

The gas produced by the union of the vapour with oils, was found to be ſimilar in its properties to phlogiſticated air, or air which had been expoſed to burning or phlogiſtic bodies; that is, it extinguiſhed flame, and poſſeſſed none of the diſtinguiſhing properties of other gaſes. *Id.* III. 211.

Oil of vitriol and ſpirit of ſalt imbibed this acid vapour. The ſpirit of ſalt thus impregnated became an aqua regia, which readily diſſolved gold; and when heated, it yielded a conſiderable quantity of nitrous gas, in the ſame manner as the impregnated water was obſerved to do. But no gas could be expelled from the impregnated oil of vitriol. *Id.* 222.

CHAP. IX.

On fluor acid Gas.

100. DR. *Prieſtley* has obtained an acid gas, by diſtilling the minerals called *fluors* with oil of vitriol, as in the proceſs for obtaining the acid of fluors. (*See Dictionary of Chemiſtry, article Fluors.*) And he has obſerved the following properties of this gas, to which he gives the name of *Fluor acid air.* Exp. and Obſerv. II. 187. and III. 285.

This acid vapour or gas no ſooner came into contact with water than part of it was abſorbed, and at the ſame time the ſurface of the water became covered with a *ſtoney film*, ſimilar to that produced by the mixture of the acid of fluors with water, and which Mr. *Scheele* pretends to be a *quartz* or *flint*. When this film was broken, another cruſt was formed on the ſurface of the water, and ſo on ſucceſſively till the whole of the gas was abſorbed by the water, which thereby becomes impregnated with a very volatile acid. As this acid is ſo readily abſorbed by water, it requires to be confined in quickſilver.

101. This gas retains its acid properties; for beſides its uniting ſo readily with water, it forms a cloud with alkaline gas, deſcribed in chap. X. and it may be abſorbed by chalk, from which it extricates calcareous gas.

102. This gas was *abſorbed* by *charcoal*, by *ruſt of iron*, and by *alum*, the ſurface of which it rendered white and opake, by ſeizing the watery part of the alum. When *ſalt-petre* was expoſed to it, the veſſel became filled with red fumes, and the gas was gradually diminiſhed till only one tenth part of it remained. One fourth part of this reſiduum was abſorbed by lime-water, in which it occaſioned a precipitation.

103. Water impregnated repeatedly with this acid gas, and freed from the earthy cruſt, being heated, was found to yield a gas which did not form any cruſt with water, but poſſeſſed all the properties which have been obſerved of vitriolic acid gas.

104. From the above properties of this fluor acid gas, Dr. *Prieſtley* is induced to think that the *fluor acid* is *not a particular acid*, but is the *acid of vitriol*, charged with as much phlogiſton as is neceſſary to give to it the form of gas, and alſo with much of the earthy matter of the fluor. And he is confirmed in this opinion from the following obſervations:

1. That fluors contain phlogiſton, appears evident from the effects of diſtilling them with nitrous acid;

by which means nitrous gas, and a gas capable of producing a precipitation in lime-water, are formed.

2. It appears no leſs evident, that an earthy matter is raiſed along with this gas, from the cruſt which is precipitated from the gas, when water is added.

3. The gas obtained by applying heat to the water impregnated with fluor acid gas, poſſeſſes all the known properties of vitriolic acid gas; the water having deprived the acid of the earthy matter which gave to it the peculiar properties of the fluor acid.

4. When nitrous or marine acids are ſubſtituted inſtead of vitriolic acid, in the proceſs of obtaining the fluor acid, none of the gas that is capable of forming a cruſt with water is produced. *Exp. and Obſerv. vol.* III. *p.* 288.

Mr. *Scheele* however affirms, that the fluor cruſt was produced, by diſtilling fluor with nitrous or marine acids.

Nevertheleſs, Dr. *Prieſtley* has remarked a difference between water impregnated with vitriolic acid gas, and water impregnated with fluor acid gas, namely, that the former is capable of being converted into ice by cold, but that the latter is not. He thinks that this difference may proceed from the earthy or fluor cruſt. *Id. vol.* III. *p.* 360.

M. *Monnet* endeavours to confirm by experiments the opinion of Dr. *Prieſtley*, that the acid obtained by diſtilling a mixture of ſpar and oil of vitriol, is not a peculiar acid, but he thinks that it is the acid of vitriol employed in the proceſs which has been rendered volatile, by combining with the earthy principle of the ſpar. He found, after he had obtained as much acid as he could by diſtillation from that mixture of ſpar and oil of vitriol, that by adding water to the acid reſiduum, he obtained more acid by diſtillation; and that the reſiduum after this ſecond operation was no longer acid. He concludes from this experiment, that the whole of the vitriolic acid is thus volatilized, and that the earth of the ſpar is rendered volatile by means of that kind of combination with the vitriolic acid, which is called *with exceſs of acid.* He further found, that a ſaline matter which he obtained by lixiviating the reſiduum, and which reſembled ſelenites, but was really different in its properties, being diſtilled in the ſame manner with vitriolic acid, the ſame volatile acid was thereby produced; and that the cruſt formed in the water of the receiver during the diſtillation of a mixture of vitriolic acid and ſpar, when deprived of its exceſs of acid by waſhing in water, became exactly ſimilar to this matter obtained by lixiviation of the reſiduum. From the acid liquor remaining in the retort, diluted with water, a white precipitate was thrown down on addition of fixed alkali, and a yellow precipitate on addition of a ſolution of mercury in nitrous acid, which yellow precipitate could not be ſublimed, and was not therefore corroſive ſublimate, according to the idea of the chemiſt, who has aſſumed the fictitious name of M. *Boullanger*, and who contends that the acid obtained in the diſtillation of ſpar with oil of vitriol is the marine. By fuſing ſpar with fixed alkali, M. *Monnet* could not obtain any neutral ſalt. *See Rozier's Journal, Auguſt* 1777.

The experiments of M. *Monnet* do not however decide the queſtion concerning the nature of the fluor acid. The acid which he obtained wanted the moſt characteriſtic property of the fluor acid, which is the power of corroding glaſs. Poſſibly there may be a difference among the ſtones called *fluors* or *fuſible ſpars.*

CHAP. X.

Of Alkaline Gas.

105. NOT only the vapour of acids, but alſo that of *volatile alkali*, may be raiſed into a permanent gas by means of heat, as Dr. *Prieſtley* has diſcovered. Thus by applying the flame of a candle to a phial containing volatile ſpirit of ſal ammoniac, he expelled much vapour, which being received into a veſſel filled with quickſilver, continued uncondenſed by cold. When mild volatile alkali was employed, he obſerved that much of the gas which combines with alkaline and calcareous ſubſtances was alſo expelled. He therefore preferred the cauſtic volatile alkali, for the purpoſe of obtaining this alkaline gas. *Exp. and Obſer.* I. 163, *&c.*

106. Alkaline gas is very readily and copiouſly *abſorbed by water*, with which it forms a very ſtrong volatile alkaline ſpirit. It alſo *diſſolves ice* as faſt as if the ice were expoſed to a hot fire. This gas *unites with the marine and vitriolic acid gaſes*, forming concrete ammoniacal ſalts; and with the *gas of calcareous ſubſtances*, with which it concretes into oblong ſlender cryſtals. *Ibid.* Although volatile alkali readily acts upon copper, yet this metal was not affected by alkaline gas. *Id. vol. II.* 232.

107. Alkaline gas, mixed with air, was found to be inflammable. *Ibid.* *Cygna* ſays alſo, that air ſaturated with volatile alkali is inflammable.

Alkaline gas was encreaſed in its dimenſions by *electric ſparks* paſſing through it; and when as much of the gas, thus treated, was abſorbed by water as could be done, the reſiduum was inflammable. *Exp. and Obſerv. vol.* II. *p.* 240.

108. In the preceding chapters the ſeveral ſpecies of gaſes, hitherto known and diſtinguiſhed from each other, by their peculiar properties, have been deſcribed. But as two or more of theſe ſpecies are frequently obtained from the ſame ſubſtance, and by the ſame proceſs; the following chapters will contain ſome obſervations relative to the kinds and quantities of gas produced from certain ſubſtances, and in the laſt chapter will be added ſome conjectures and ſpeculations concerning the theory of theſe fluids.

CHAP. XI.

On the Gas extricated from putrefying Subſtances.

109. A Permanently elaſtic fluid, or gas, eſcapes from animal and vegetable ſubſtances undergoing the putrefactive fermentation.

This gas conſiſts of two different kinds mixed together. One of theſe renders cauſtic alkalies mild, and precipitates lime-water, as Dr. *Mackbride* has ſhewn. The other kind of gas was obſerved by Mr. *Cavendiſh* to be *inflammable*. *See Chap. IV. on inflammable gaſes.*

In order to aſcertain the quantity and proportion of theſe two gaſes, Dr. *Prieſtley* put a piece of mutton, weighing four pennyweights and ſix grains, into a jar filled with quickſilver, and inverted into quickſilver, and he found that the quantity of gas emitted during the putrefactive proceſs, was, in bulk, equal to $2\frac{11}{14}$ ounces of water, of which quantity $2\frac{15}{200}$ ounce meaſures were of the former kind of gas, and the remainder was inflammable. It is obſervable, that all the inflammable gas was extricated in the beginning of the proceſs. *Exp. and Obſ. vol.* III. 344.

From 7640 grains of putrefying broth, (which contained about 163 grains of ſolid matter) one grain of inflammable gas was procured by Mr. *Cavendiſh*. *Phil. Tranſ.* 1766.

CHAP. XII.

Of the Gas obtained by Fire from Animal and Vegetable Subſtances.

110. MUCH elaſtic fluid is produced in the diſtillation of animal and vegetable ſubſtances. Dr. *Hales* has aſcertained the quantity of gas which he procured from many of theſe ſubſtances. From his *Analyſis of Air*, the following ſummary of the reſults of his experiments is collected:

1 cubic inch of *hog's blood*, yielded	33 cubic inches of gas.		
½ cubic inch of *deer's horn* - - -	117		equal to one ſeventh of its wt.
½ cubic inch of *oak*	108	—	one third ditto.
388 grains of *Indian wheat*	270	—	one fourth ditto.
1 cubic inch of *peaſe*	396	—	one third ditto.
437 grains of *muſtard ſeed*	270	—	one ſixth ditto.
142 grains of dry *tobacco*	153	—	one third ditto.
1 cubic inch of *oil of aniſeed*	22		
1 cubic inch of *oil of cloves*	88		
1 cubic inch of *honey* mixed with *calcined bones*	144	—	one ninth ditto.
1 cubic inch of *bees-wax*	54	—	one tenth ditto.

1 cubic inch of *coarſe ſugar*, yielded	126 cubic inches,	equal to one tenth of its weight.
1 cubic inch of *tartar*	504 —	one third ditto.
½ cubic inch of *ſalt of tartar*	112 --	one ninth ditto.
¼ cubic inch of *human calculus*	516	
½ cubic inch of *ſtones* taken from a human gall bladder	108	

Van Helmont computes that of 62 pounds of *charcoal* 61 pounds may be reduced into gas by burning. *Complex. atq. miſtion. elem. figm.* 13.

It may be remarked generally, that the elaſtic fluid, produced by fire from animal and vegetable matters, is chiefly a mixture of *calcareous gas*, deſcribed in chap. III. and of another gas which is *inflammable*, and which may be ſeparated from the former by expoſure to water; by which means the inflammable gas will be left alone, the other being almoſt totally abſorbed by the water. The inflammable gas thus obtained ſeparate from the other, is not quite pure; for I found that a gas obtained by diſtilling tartar, which did not ſhew any marks of its containing air when mixed with nitrous gas, being expoſed to water and lime-water till no more could be abſorbed, left a reſiduum which was inflammable, and which, on being mixed with nitrous gas, became turbid, and was a little diminiſhed; which ſhews that the reſiduum contained a ſmall portion of air, mixed with the inflammable gas.

CHAP.

CHAP. XIII.

Of the Gaſes in Mines and other ſubterraneau Places.

111. A Noxious gas is found in many caverns, as in the famous *Grotta del Cane*, in mines, wells, and other deep pits. This gas, which by *Engliſh* miners is called *Choke-damp*, is heavier than common air, and therefore lies chiefly at the bottom of pits; extinguiſhes flame; precipitates the lime of lime-water; and is noxious to animals: from theſe properties, which it poſſeſſes in common with the gas obtained from calcareous and alkaline ſubſtances, it has been reckoned to be of the ſame kind, as that which has been deſcribed under the name of *calcareous gas*. See Chap. III.*

112. Another kind of gas found in mines and other deep pits, is called *Fire-damp*, from its inflammability. It is lighter than air, floats near the roofs of mines, and is apt to catch fire and explode. This is one of the gaſes which have been enumerated under the name of *Inflammable gas*. *See Chap. IV.*

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* Miners who work in mines that are ſubject to this damp, generally carry down with them, into their pits, a lighted candle to try the ſalubrity of the air. They can, however, remain with ſafety ſeveral hours in pits where a candle cannot burn. I have ſeen them working in the ſhaft of a coal-pit ſeveral yards below the part of the ſhaft where a candle was extinguiſhed. For, as has been already obſerved, in treating of calcareous gas, flame may be extinguiſhed by mixing a ſmaller quantity of noxious gas with air than is ſufficient to prevent reſpiration: but where the damp is ſo ſtrong, that not only the flame of the candle, but alſo the redneſs of the burning wick is extinguiſhed, the miners never venture to remain a minute, knowing that degree of damp to be quickly fatal to animal life.

CHAP. XIV.

Of the Gas of Waters.

113. AN elaſtic fluid may be expelled from *common water*, by *removing the preſſure of the atmoſphere*, or by *boiling*. But although the greater part of the air or gas may be expelled by theſe means from water, yet M. *de Luc* ſhews, from many laborious experiments, that water obſtinately retains a certain quantity of air or gas, which cannot be extricated by boiling, by the air-pump, or by any other known means, than by a long-continued agitation in vacuo; and he further ſhews, that when water is thus deprived of all the air that can be ſeparated from it, it then becomes capable of ſuſtaining, without boiling, a much greater heat than can be given to it in its common ſtate, even to 240° of *Fahrenheit*'s ſcale, or more. The elaſtic fluid contained in water, may be alſo ſeparated by *freezing*. Accordingly *ice* is always obſerved to contain many bubbles.

From 54 cubic inches of well-water, Dr. *Hales* obtained one cubic inch of elaſtic fluid; and from a pint of pump-water Dr. *Prieſtley* procured one quarter of an ounce meaſure of a gas; in which a candle could not burn, but a mouſe lived. *Exper. and Obſ. vol. I.* 160. The water of another pump yielded one fourteenth of its bulk of gas. *Id. vol. II.* 223.

A much larger quantity of gas is contained in many *mineral waters*. Thus from 411 ounces of the water of *Rathbone place*, Mr. *Cavendiſh* obtained above 75 ounce meaſures of gas, of which quantity he obſerves, not above twenty meaſures were extricated before the water boiled. *Philoſ. Tranſ. vol. LVII.*

Some authors talk of a much larger quantity of gas being contained in water. Thus *Mariotte* affirms that a bubble of elaſtic fluid, expelled by heat from water, did occupy, when reduced to the temperature of the atmoſphere, a ſpace, ten times greater than the ſpace occupied by the water which had contained it.

But Dr. *Hales* ſuſpects that part of this gas produced in *Mariotte*'s experiment, (which was made by applying heat to a drop of water included in a glaſs thimble filled with oil and inverted in oil) proceeded from the *oil:* for oil alſo contains a conſiderable quantity of gas, according to Dr. *Hales*'s experiments. *Hales, Appendix.*

Other mineral waters yield a very ſmall quantity of gas by being heated. From 54 cubic inches of *Pyrmont* water, Dr. *Hales* procured two cubic inches of gas, which he ſeems to have erroneouſly conſidered as air. *Bath* water yields only one thirtieth of its bulk of gas, according to an experiment of Dr. *Prieſtley*; and of this quantity, one half had the properties of calcareous gas, and the other half of air in which a candle had burnt out. *Exper. and Obſerv. vol. II. p.* 223. Dr. *Hales* procured no more gas from two quarts of *Bath* water, than was equal in bulk to half a pea. *Appendix.*

114. Dr. *Hales* juſtly attributed the peculiar briſkneſs and ſparkling quality of *Pyrmont* and other mineral waters to the gas which he found was contained copiouſly in them. *Hoffman* alſo obſerved, that ſome mineral waters in *Germany* contained nothing ſaline, but that they abounded in a volatile principle, to which he gives the name of *ſulphureous aereo-ethereo elaſtic ſpirit.* And Mr. *Venel* ſhewed in 1750, that the waters of *Seltz* were neither acid nor alkaline, but

contained one fifth of their bulk of an elaſtic fluid, to which they owed their peculiar properties: and he endeavoured to imitate this mineral water, by adding to a *French* pint of water two gros of mineral alkali, and a ſufficient quantity of marine acid, to ſaturate the alkali. This mixture being made in a ſtrait-necked cloſe veſſel, the gas which was expelled from the alkali by means of the acid was not allowed to eſcape; but it impregnated the water ſo ſtrongly, that this water was found to contain twice as much gas as the native mineral water.

Mr. *Venel* does not however diſtinguiſh the gas contained in mineral waters from air.

Dr. *Seyp* of *Pyrmont* in the year 1736 conſidered this fluid to be the ſame as that which is found in the *Grotta del Cane*, and other ſubterranean places: and Dr. *Brownrigg* ſent to the Royal Society a paper, in which the gas of *Pyrmont* and *Spa* waters is ſaid to be analogous to the choke-damp or permanently elaſtic gas of mines, which is ſhewn in chap. XIII. to be that gas which is in this Treatiſe called *calcareous*. Phil. Tranſ. vol. LV.

Mr. *Cavendiſh* obſerved, that the gas obtained from the waters of *Rathbone-place* occaſioned a precipitation in lime-water; and he is induced to believe, that the greateſt part of it is of the ſame nature as the gas contained in calcareous earths: but he alſo found, that $\frac{875}{7500}$ of the elaſtic fluid contained in this water were air.

115. Mr. *Cavendiſh* diſcovered that calcareous earth is ſuſpended and diſſolved in the waters of many ſprings, by means of their contained gas. By an accurate analyſis of the waters of *Rathbone-place*, he obtained, from 494 ounces of theſe waters, 271 grains

of earth, which, excepting a few grains of magneſia, was of the calcareous kind. He further ſhews, as has been already remarked, that the gas obtained from calcareous or alkaline ſubſtances is capable of diſſolving calcareous earth, that is, of making it ſoluble in water. It may ſeem extraordinary that this gas, which is known to precipitate the lime from lime-water, ſhould alſo render this earth ſoluble in water; but the fact is uncontrovertible; for beſides that this or ſome very ſimilar gas is proved to be the medium by which the calcareous earth is kept ſuſpended in *Rathbone-place*, and other waters, it is ſhewn by Mr. *Cavendiſh*, that if to lime-water, which has been rendered turbid by means of calcareous gas, more of the ſame gas be added, this water will, by this addition, be enabled to rediſſolve the precipitated lime, and will be again rendered pellucid. And indeed this phenomenon is analogous to other well-known chemical facts. For many of the precipitates, formed by adding alkalies to the ſolutions of metals in acids, may be rediſſolved by a further addition of the alkaline precipitant.

116. Mr. *Lane* has ſhewn that the gas of mineral waters is capable of *diſſolving iron*; and that by means of this fluid, without any other menſtruum, the iron is diſſolved and ſuſpended in many chalybeate waters. Theſe chalybeate waters depoſite their iron when expoſed to air; for the gas, by means of which it is ſuſpended, is volatile, and eſcapes upon expoſure to air *.

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* Dr. *Hales* has obſerved, that when *mineral waters* had been deprived of their elaſtic fluid, they loſt their power of tinging an infuſion of galls. (*Appendix.*) And indeed *Van Helmont*, long before, knew that the eſcape of the ſpirituous gas, from theſe waters, by expoſure to air, was accompanied with a loſs of their acidulous

But Dr. *Brownrigg* has obſerved, that the gas does not eſcape from the water which it impregnates, unleſs the water be in contact with air; for when the *Pohun* water was excluded from air, but at the ſame time liberty was given for its gas to riſe into an empty bladder, the gas did not ſeparate from the water by any ſpontaneous motion, but on the contrary, it remained united with the water, when expoſed to the greateſt heats of our climate. When the impregnated water is thus excluded from air, the gas will eſcape but ſlowly with any heat leſs than that of 110° of *Fahrenheit*'s thermometer, although ſuch heat be ſufficient for the diſtillation of water; neither can this gas be wholly expelled by a heat of 160° or 170°, continued two hours. This adheſion ſhews, that the gas exiſts in the mineral water with the other ingredients in a ſtate of ſolution; and in the ſame proportion in which the gas is expelled, in the ſame alſo are the martial and earthy parts ſeparated. *See Dr. Brownrigg's paper on Pohun waters, Phil. Tranſ. vol. LXIV.*

There is reaſon to believe that the gas may be more intimately combined with the ingredients of ſome mineral waters than with thoſe of others, and cannot be ſo eaſily expelled. Dr. *James Keill* obſerved, that a mineral water near *Northampton* loſt its ſpirituous quality, by being long kept included in a *Florence* flaſk hermetically ſealed. The combination of the gas with the water may have been rendered more perfect by time. Perhaps the reaſon why ſo little gas can be extricated from *Bath* water, (ſee §. 113.) may be, that it is more intimately combined with that

water,

dulous quality, and a depoſition of the ferruginous matter diſſolved in them. *Paradoxum quartum*, §. 2, 9, 10.

water, or united with other ingredients which retain and fix it more than in the waters of *Pyrmont*, and others which ſparkle much.

117. Gas may be *ſeparated from water*, not only by the means mentioned in §. 113, but alſo by addition of an acid, which occaſions an effervęſcence, and conſequently an eſcape of the gas. Hence the acidulous waters are made to ſparkle, by adding juice of lemons, or *Rheniſh* wine.

118. The diſcovery of gas being the principle to which the briſkneſs and peculiar properties of the mineral waters called acidulous are principally owing, having been aſcertained; and Dr. *Hales* and Mr. *Cavendiſh* having ſhewn, that the gas of calcareous ſubſtances was capable of being abſorbed by water, it occurred to Dr. *Prieſtley*, that the artificial impregnation of water with gas might be applied to uſeful purpoſes, and that mineral waters might be thus imitated. It was obſerved, that the water which had been diſtilled from ſea-water, although free from any ſaline matter, was not ſo palatable or briſk as pump-water. This defect Dr. *Prieſtley* propoſed to ſupply, by impregnating the diſtilled water with the gas extricated from chalk by means of oil of vitriol. And he publiſhed an account of an eaſy method of effecting this impregnation. His method conſiſted in collecting a ſufficient quantity of his gas in a bladder, and in forcing the gas from the bladder through a bent tube into the water intended to be impregnated; which water was contained in a bottle inverted into a baſon filled alſo with water. The gas thus remaining in contact with the ſurface of the water within the inverted bottle, is gradually abſorbed, and the abſorption is haſtened, by agitating the apparatus. The

water,

water, by being impregnated, acquires the taſte of the acidulous mineral waters; and accordingly this artificial impregnation of water with gas has been lately much practiſed, in order to imitate theſe mineral waters. Dr. *Percival* obſerved, that the water thus impregnated acquires more of the ſparkling quality of *Pyrmont* water, by being kept ſome time. *Exper. and Obſerv. vol. I. p.* 32.

This impregnation of water with gas is much facilicated by Dr. *Nooth*'s invention of an elegant and well-contrived apparatus of glaſs veſſels for this purpoſe, an account of which is publiſhed in the *Philoſ. Tranſ. vol. LXV. See alſo Plate, fig.* 4, *and the explanation.*

119. The gas contained in water is ſaid by ſome authors to be *more expanſive* than air is; that is, that by an equal diminution of preſſure upon theſe two elaſtic fluids, the bulk of the former is much more enlarged than the bulk of the latter. *S'Graveſande* obſerved, that a bubble of the gas in water expanded ſo as to occupy a ſpace 15000 times greater; when the common air ſuffered an expanſion of only 300 times. And *Muſchenbroek* affirms, that he has ſeen a particle of this gas expand itſelf to a ſize 46,656,000,000 times greater. But, he adds, ſuch particles are not always to be obſerved in water; and he conjectures that this gas, as well as air, conſiſts of particles of different denſities and elaſticities. *Introd. ad Philoſ. Nat.* §. 2051. 2063.

That theſe ſingular expanſions of bubbles of gas in water appeared as is repreſented, cannot be doubted, when we conſider the accuracy and ability of *s'Graveſande* and *Muſchenbroek*. But that the gas of water poſſeſſes an elaſticity ſo much greater than air, is an inference not eaſily to be admitted. And may not this phenomenon be otherwiſe explained? Water and other liquids are known to retain ſo powerfully the air or other elaſtic fluids which happen to be united with them, that theſe elaſtic fluids cannot be *immediately* thence expelled, either by boiling or by removing the preſſure of the atmoſphere; but while the liquids remain freed from this preſſure, the air or other elaſtic fluid ſeparates from them very ſlowly and gradually, forming a bubble which becomes more and more large, from the gradual acceſſion of exceedingly ſmall and almoſt inviſible particles of ſuch elaſtic fluid. This very ſlow ſeparation of air from liquors, and the gradual formation of bubbles, was particularly noticed by M. *de Luc* when he was making thermometers. It ſeems therefore probable, that the enlargement of the bubbles obſerved by the *Dutch* philoſophers, did not proceed merely from an expanſion of a given quantity of air or other elaſtic fluid, but principally from the acceſſion of more particles of this fluid diſengaging themſelves from the water during the experiment, and uniting with the bubbles ready formed.

Muſchenbroek ſays alſo, that by *doubling* the preſſure he reduced the elaſtic vapours of a fermenting paſte to a quarter of its former ſpace: and he thinks that moſt elaſtic fluids are not ſubject to the ſame law as air is, namely, that the ſpaces occupied by them are inverſely as the powers with which they are compreſſed. *Introd. ad Phil. Nat.* §. 2051.

As *Muſchenbroek* does not relate the manner in which the abovementioned experiment was made, we cannot ſay whether ſome error might not ariſe from condenſation of watery vapours, or from any abſorp-

tion

tion of gas. A different reſult however was the conſequence of the following experiment.

I filled a bent tube open at one end only with ſome gas obtained by adding vitriolic acid to chalk. By pouring mercury into the tube, a quantity of this gas was included between the cloſe end of the tube and the ſurface of the mercury. I meaſured the ſpace occupied by the gas thus expoſed to the compreſſion of the atmoſphere, and alſo of the column of mercury in the open leg of the bent tube above the ſurface of that fluid in its cloſed leg. I then varied the height of this column, by pouring more mercury into the tube, and I obſerved the reſpective diminutions of ſpace which the gas ſuffered from the encreaſed compreſſions. By comparing the ſeveral obſervations which I had made, I found that the ſpaces occupied by the gas, under different preſſures, were to each other inverſely as their reſpective compreſſing forces, and conſequently that this elaſtic fluid is ſubject to the ſame law, in this reſpect, as common air is. *

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* The bulk of every permanently elaſtic fluid is probably in the inverſe proportion to its preſſure, with the ſame *heat*. But as concrete bodies are ſubject to very different expanſions by equal degrees of heat, ſo alſo are gaſes. Dr. *Prieſtley* has made experiments to meaſure the expanſions of ſeveral of theſe fluids, while the mercury of *Fahrenheit*'s thermometer was expanded 10 degrees. The proportions of theſe expanſions to each other are expreſſed in the following table.

Common air	1.32	Deflagrating air	2.21
Inflammable gas	2.05	Phlogiſticated air	1.65
Nitrous gas	2.02	Vitriolic acid gas	2.37
Calcareous gas	2.20	Alkaline gas †	4.75
Marine acid gas	1.33		

† Dr. *Prieſtley* expreſſes ſome doubt of the accuracy of his experiments concerning alkaline gas. *Vol. III.* 347.

CHAP. XV.

On Fulminating Gaſes.

120. SOME gaſes are *ſo ſuddenly* extricated or formed from the ſubſtances containing them, by the heat applied, or by means of the action of the parts of theſe ſubſtances on each other, or by the concurrence of both theſe cauſes, that in the inſtant of their formation an *exploſion* or *fulmination happens.*

121. A gas of this kind is produced by the *deflagration of nitre* with inflammable ſubſtances. Hence the exploſion of *gun-powder*, and of the *fulminating powder* compoſed of nitre, ſalt of tartar, and flowers of ſulphur.

The quantity of gas obtained from gun-powder was found by the experiments of Mr. *Robins** to be equal in bulk to 244 times the bulk of the exploded gun-powder, when this gas is compreſſed by the atmoſphere and reduced to the ſame heat: and as the expanſion of the air appeared, from his experiments, to be encreaſed four times by the heat of iron juſt beginning to be white, he infers, that if the elaſtic fluid of gun-powder be equally affected by heat as air is, its expanſive force, in the inſtant of exploſion, is nearly a thouſand times greater than the preſſure of the atmoſphere; a force ſufficient to produce the effects of gun-powder.

Boyle obſerved that the gas of gun-powder was *noxious* to animals; and Dr. *Prieſtley* found, that the gas obtained by applying heat to a mixture of nitre and ſulphur was the *nitrous gas*. Exper. and Obſervat. vol. II. p. 90.

122. Some

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* On Principles of Gunnery.

122. Some *metallic precipitates* are capable of fulminating. The preparation called *fulminating gold* is well known. The gas produced during its exploſion has not been examined.

Mr. *Bayen* has diſcovered that various *mercurial precipitates* fulminate, when they are triturated with about one ſixth part of flowers of ſulphur, and afterwards heated. Of theſe precipitates the following are the principal.

a. Precipitates made by adding a *fixed alkali*, *mild* or *cauſtic*, or a *volatile mild alkali*, or *lime-water*, to a ſolution of *mercury* in *nitrous acid*.

b. Precipitates made by adding *fixed alkalies mild* or *cauſtic*, or *lime-water*, to a ſolution of *corroſive ſublimate* in water.

c. A precipitate or *mercurial calx* prepared by digeſting, in a ſand-bath, *turbith mineral*, with a ſolution of *fixed alkali* in water, till the precipitate became red.

Mr. *Bayen* remarks, that no detonation was produced by mixing theſe precipitates with powdered charcoal, and applying heat to the mixture; and alſo, that the detonation, by means of ſulphur, was obſerved to be ſo much the ſtronger, as the precipitates were more deprived of their acid. Thus the precipitate from the ſolution of mercury in nitrous acid, by means of volatile alkali, detonated very weakly, till it had been previouſly deprived of much of its adhering acid by calcination: and no detonation was produced by the precipitate which had been made by adding volatile alkali to a ſolution of corroſive ſublimate in water; for it appeared, upon expoſing this precipitate to a ſubliming heat, that the whole of it was in the ſtate of ſweet mercury, and that conſequently much acid adhered to it.

123. The detonation of nitrous and other fulminating powders, is an effect too ſtriking not to have engaged the attention of philoſophers. *Stahl* maintains that the water of the nitre is converted into air. Mr. *Macquer* very ingeniouſly conjectures that, in the operation, a *nitrous ſulphur* is formed, which inflames at the inſtant of its formation. *See the article, Detonation of Nitre, of the Dictionary of Chemiſtry.*

Dr. *Black* is of opinion, that the fulminating gold derives its detonating property from ſome gas which adheres to it, and which it had received from the alkaline precipitant uſed in the operation. However this explanation may be applicable to the fulminating gold, it cannot be applied to explain the fulmination of the *mercurial precipitates* of Mr. *Bayen*; for ſome of theſe were precipitated by cauſtic alkalies, and by lime-water. Mr. *Bayen* thinks that the fulmination of theſe precipitates is the conſequence of a commotion excited between the mercury and the ſulphur at the inſtant of the combination taking place, by which cinnabar is formed. And this opinion is confirmed by the heat, and even ſpontaneous inflammation which happens when ſulphur and crude mercury combine together.

Whatever be the cauſe which excites ſuch commotions, the *detonation* itſelf conſiſts in the ſudden concuſſion which the air receives from the inſtantaneous production of an elaſtic fluid expanding itſelf with great violence. In the notes to the firſt *Engliſh* edition of the Dictionary of Chemiſtry I ſuggeſted, at the article *Fixable Air*, that the elaſtic fluid produced in the detonation of nitre was formed from the *nitrous acid* probably combined with the *inflammable principle*, and that theſe are *converted into the ſtate of gas* by the violence of the action of this acid and of the inflammable matter on each other. This opinion of the *converſion of nitrous acid into gas*, by the *detonation of nitre*, has been ſince confirmed and eſtabliſhed by late experiments, which ſhew firſt, that the gas thereby produced is principally that which we have deſcribed under the name of *nitrous gas*; and ſecondly, that this nitrous gas is the nitrous acid in the ſtate of *gas*, probably combined with inflammable matter, and is again convertible into the liquid nitrous acid, by being mixed with air.

The detonation likewiſe of Mr. *Bayen*'s mercurial precipitates is occaſioned by the production of an elaſtic fluid; and I think that this fluid alſo proceeds from the converſion of ſome adhering portion of the acid, in which the mercury had been diſſolved, into the ſtate of gas, (together probably with ſome of the phlogiſton of the metal or ſulphur) by means of the violent heat and motion excited between the mercury and the ſulphur in the act of combination, while the mercury is forced from its union with the adhering acid. For it appears, both from Mr. *Bayen*'s experiments, and from the analogy of other precipitations, that ſome acid always adheres to the precipitate; and probably alſo ſome of the alkaline or earthy precipitant. It is true indeed, that when *much* acid adheres, the fulmination does not happen, as Mr. *Bayen* remarks. The reaſon of which may be, that the combination between the mercury and ſulphur is by this abundant acid ſo prevented or retarded, that the heat and motion requiſite to effect the converſion of acid into gas are not produced.

It appears further, from Mr. *Bayen*'s experiments, that not only the nitrous acid but alſo the *marine acid* is *capable of detonation*, and, according to the above conjectures, of being *converted into gas*.

CHAP. XVI.

Conjectures and Speculations concerning the Theory of Gaſes.

124. WE daily ſee the ſame bodies aſſume very different appearances or ſtates, under different circumſtances; and of ſuch changes, no inſtances can be adduced more curious and ſurprizing than thoſe which we have deſcribed concerning the formation of the various kinds of permanently elaſtic fluids. We have ſeen that ſolid, hard, and denſe bodies loſe at once their coheſion, acquire a repelling force, and ſuddenly expand into a ſpace many hundred or thouſand times greater than that which they before occupied; forming rare, inviſible, elaſtic fluids. We have alſo ſeen that the moſt expanſive fluids can be again reſtored to a concrete ſtate, and may conduce to the formation of very hard and ſolid bodies.

To explain theſe changes, exceeds, I fear, the limits of our preſent phyſical knowledge. Conjectures however may be admitted; which, as they are not intended to decide, do not eſtabliſh or confirm errors, but may be uſeful, by ſuggeſting certain queſtions to be aſcertained by future experiments. With this view then only we proceed to the following ſpeculations.

125. Many well known facts ſhew, that matter is endowed with two contrary qualities, an *attractive* and a *repulſive power*, of which ſometimes one, and ſometimes the other exerts itſelf in different circumſtances. Natural philoſophers have obſerved, that the particles of bodies attract each other within certain diſtances; and that, when they are placed beyond the ſphere of each other's attraction, they begin to exert a repulſive power. In order therefore to change a co-

hering concrete body into a repelling fluid or gas, is it not ſufficient that the particles of that body be removed to a diſtance from each other, greater than the ſphere of their attraction, that their repulſive force may begin to act †?

May not *heat*, which is known to expand all bodies, remove their particles to ſuch diſtances from each other, that their attraction ſhall ceaſe, and their repulſion commence? And is not this the mode of action by which heat raiſes water, mercury, and other volatile bodies, into elaſtic vapours; ſome of which by cold are again brought within the ſphere of each other's attraction, and are condenſed; while others, poſſeſſed of a ſtronger repulſive power, remain in an expanded ſtate, forming ſome of the permanent elaſtic fluids, called *gaſes*.

126. May not alſo a *violent motion* or *quick vibration*, excited among the minute particles of bodies, occa-

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† Thus *Sir Iſaac Newton* ſays, (*Optics*, *Quer.* 31.) "As in "algebra, where affirmative quantities vaniſh and ceaſe, there "negative ones begin; ſo in mechanics, where *attraction* ceaſes, "there a *repulſive* virtue ought to ſucceed. And that there is ſuch "a virtue, ſeems to follow from the reflections and inflections of the "rays of light. For the rays are expelled by bodies in both "theſe caſes, without the immediate contact of the reflecting or "ineffecting body. It ſeems alſo to follow from the emiſſion of "light; the ray ſo ſoon as it is ſhaken off from a ſhining body by "the vibrating motion of the parts of the body, and gets beyond "the reach of attraction, being driven away with exceeding great "velocity. For that force, which is ſufficient to turn it back in "reflection, may be ſufficient to emit it. It ſeems alſo to follow from "the production of air and vapour. The particles when they are "ſhaken off from bodies by heat, or fermentation, ſo ſoon as they "are beyond the reach of the attraction of the body, receding "from it, and alſo from one another with great ſtrength, and "keeping at a diſtance, ſo as ſometimes to take up above a mil"lion of times more ſpace than they did before in the form of a "denſe body."

ſion a ſimilar ſeparation of theſe particles, and a conſequent change from a concrete to a repelling ſtate? Thus the particles of fire and light are ſuppoſed by *Sir Iſaac Newton* to be thrown off from ignited or luminous bodies, by the motion and vibration of their parts. May not alſo the violent inteſtine motion excited in the particles of bodies, during their *decompoſition* and *ſolution by menſtruums*, as of *metals by acids*; and alſo of bodies undergoing the *vinous, putrefactive*, or *other fermentations*, produce in the ſame manner the gaſes which are known to be formed in theſe ſeveral operations? For when any two united particles are torn aſunder, by the ſuperior attraction or affinity of a menſtruum, or ſolvent, muſt they not, at the inſtant of ſeparation, recede from each other with a force equal to that with which their disjunction was reſiſted; in the ſame manner, as the two parts of a cord, ſtretched till it breaks, recoil towards the oppoſite points of tenſion? And the effects of the violent ſeparations of the particles of bodies, which occur in chemical decompoſitions, ſolutions, and fermentations, will appear very great, when we conſider the *minuteneſs* of the particles engaged in theſe operations, and how much the activity, or force of the attraction and repulſion of bodies, depends on the minuteneſs of their ſize. For it is known, that the attraction of any two bodies to each other, encreaſes as the diſtance between them decreaſes, in ſome high ratio; and as the diſtance at which all the particles of any body can exert their attractive power upon any other contiguous body, may be ſuppoſed equal to the ſemi-diameter of the attracting body; therefore the particles of large bodies muſt exert that power at a greater diſtance than thoſe of ſmaller bodies, and conſequently the attractive force of large bodies muſt be leſs than that of ſmaller bodies, relatively to the quantity of matter contained in each.

127. Some bodies are more diſpoſed than others to be changed from a concrete to an elaſtic ſtate. Thoſe which cohere with leaſt force, will moſt eaſily have their particles thrown out of the ſphere of each other's attraction. And this ſeems to be the caſe with all thoſe bodies which are called *volatile*, as water, ſpirit of wine, and ether. And is not even the *evaporation* of cold water, and of ſome other volatile liquids, eſpecially in vacuo, occaſioned by ſome of the particles, at the ſurfaces of theſe liquids, where they are not compreſſed by other particles, being thrown by the agitation, which generally prevails in fluid bodies, to ſuch diſtances, that their repulſive force can begin to exert itſelf*?

Thoſe bodies which are eaſily expanded to an elaſtic ſtate, are alſo eaſily reducible to their former ſtate, and are generally condenſable by cold into bodies of the ſame ſpecies, as they were of before their volatilization. For, as their coheſive power is weak, ſo alſo is their repulſive power; and therefore cold, which approximates the particles of bodies, is capable of bringing them again within the ſphere of each other's attraction.

But bodies, on the other hand, whoſe parts cohere ſtrongly, and which, therefore, cannot be disjoined without violent efforts, ſuch as thoſe which produce the ſolution and decompoſition of bodies, whether by heat, by acid menſtruums, or by fermentations, form elaſtic fluids, whoſe repulſive power is ſtronger, and which cannot be condenſed merely by cold. The violence of the effort employed in theſe operations, appears from the heat with which they are accompanied. From ſuch bodies, therefore, are chiefly formed the uncondenſable fluids, called *Gaſes* †.

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* Some philoſophers have attributed the riſe of exhalations and of vapours to the diſſolving power of air, exerted upon the moiſture on the ſurface of the earth. But although this cauſe may concur, it does not ſolely or principally produce this effect; for water is known to evaporate not only in air, but alſo in vacuo.

128. Of all the concrete bodies which we know, none poſſeſſes ſo ſtrong and general an attractive power as *acids* do; for they are known to unite and combine with water, oils, earths, and metals. Nor do perhaps any bodies reſiſt their action, excepting thoſe compounds which are already ſaturated with acid, as ſulphur is. When we conſider the great activity of acids, and alſo how much the activity of bodies depends on the minuteneſs of their particles, does it not ſeem probable, that the particles of acids are very minute, and that to this minuteneſs of ſize, theſe bodies owe their ſtrong attractive diſſolving power?

129. There is another body which never appears to us in a concrete ſtate, unleſs when combined with other ſubſtances, but which ſeems ſtrongly diſpoſed to unite with every other claſs of bodies, excepting,

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† "The particles of fluids which do not cohere too ſtrongly, "and are of ſuch a ſmallneſs as renders them moſt ſuſceptible of "theſe agitations which keep liquors in a fluor, are moſt eaſily ſeparated and rarefied into vapour, and in the language of chemiſts "are volatile, rarefying with an eaſy heat, and condenſing with "cold. But thoſe which are groſſer, and ſo leſs ſuſceptible of agitation, or cohere by a ſtronger attraction, are not ſeparated "without a ſtronger heat, or perhaps not without fermentation. "And theſe laſt are the bodies which the chemiſts call fixed, and "being rarefied by fermentation, become true permanent air. "Thoſe particles receding from one another with the greateſt force, "and being moſt difficultly brought together, which upon contact "cohere moſt ſtrongly." *Newton's Optics*, *Quer.* 31.

perhaps, water, with which it does not ſeem to be capable of combining, but by the intervention of acids. This is the *matter of light*; thoſe minute particles which have been repelled from the ſurface of the ſun, and other ignited bodies; and are abſorbed and combined with acids, and earths, forming the various combuſtible matters, vegetable, animal, and mineral *.

Theſe matters it endows with the property of inflammability, and hence it is called by chemiſts, *Phlogiſton*.

Now the amazing tenuity of the matter of light is well known; and from this property perhaps ariſes its extreme ſuſceptibility of that motion on which heat depends, and the violence with which it combines with thoſe ſubſtances which it moſt ſtrongly attracts. From this ſuſceptibility of motion, muſt not the particles of the matter of light be peculiarly diſpoſed to be agitated and thrown from the ſphere of each other's attraction, and to exert the repulſive faculty? Accordingly, not only light itſelf poſſeſſes eminently this repulſive faculty, but alſo the ſubſtances with which this matter is combined are thereby rendered more volatile, as numberleſs chemical facts demonſtrate.

As therefore the matter of light is ſtrongly diſpoſed to become volatile, and to exert its repellent force; and as it imparts more or leſs of this property to the various ſubſtances with which it is capable of combining, it ſeems particularly adapted to form elaſtic fluids. Accordingly, it may be doubted whether, in each of the above-deſcribed gaſes, ſome portion of phlogiſton does not enter. But ſcarcely any ſubſtance is ſo much diſpoſed to unite with phlogiſton as acids are; and as theſe are endowed with ſo ſtrong an attractive power, they are probably poſſeſſed of an equally ſtrong repellent power, when they happen to be thrown into an elaſtic ſtate, and conſequently are very capable of being converted together with phlogiſton into permanent gaſes. Accordingly we ſhall find, upon examination of the preceding hiſtory of theſe fluids, that in the formation of moſt of them, an acid and phlogiſton enter into the compoſition of the ſubſtances employed.

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* "Are not *groſs bodies* and *light* convertible into one another, "and may not bodies receive much of their activity from the par- "ticles of light which enter their compoſition?" *Newton's Optics, Quer.* 30.

Phlogiſton is alſo much diſpoſed to unite with alkaline and other earths, eſpecially thoſe that are metallic. And accordingly, among the fluids above deſcribed, a few will be found which ſeem to conſiſt principally, if not ſolely, of phlogiſton and ſome portion of earth.

As water is powerfully attracted by acids, and is itſelf diſpoſed to aſſume an elaſtic ſtate, (though not permanent) it may alſo enter into the compoſition of theſe fluids, and thus acquire, by means of the other component parts, a permanent elaſticity.

130. From theſe ſubſtances, then, phlogiſton, and acids, together with ſome portion of earth or of water, may not the ſeveral gaſes deſcribed in the preceding pages be compounded? To enable us to reſolve this queſtion, let us take a ſurvey of theſe fluids: but it may be proper previouſly to obviate an objection which will readily occur, viz. that ſo many fluids, ſo different in their properties, ſhould conſiſt of ſo few and the ſame elements.

Firſt, it may be remarked, that a great variety of compounds might ariſe from the difference of the kinds of acids and of earths employed in the proceſſes for producing gaſes. Thus by the ſame proceſs, by varying the acid, may be produced, marine acid gas, vitriolic acid gas, or nitrous acid gas.

Secondly, this variety may, and does principally proceed from the diverſity in the *mode of combination.* For if any two bodies, A and B, are capable of uniting and combining together chemically, there are two modes in which they can combine; the one in which A predominates, and the other in which B predominates. Thus air unites with, and diſſolves a certain portion of water, (*ſee* §. 8.) and thus a compound is formed, in which air predominates. But water is alſo known to diſſolve a certain portion of air, (*ſee* §. 9.) and a compound is thus formed, in which water predominates. Thus alſo ether diſſolves a certain determinate proportion of water, forming a compound in which the ether predominates; and water diſſolves a certain determinate proportion of ether, forming a compound in which the water predominates. Accordingly, if more water be added to any quantity of ether, than this quantity of ether can diſſolve, (but not ſo much as to be able to form the whole ether into the compound in which water predominates) two diſtinct compounds will be formed, one floating upon the other, in one of which the ether predominates, and in the other the water predominates; and there will not be beſides any other compound or mixture conſiſting of other proportions of theſe liquids. Thus too quicklime and water combine in two different modes, forming *ſlaked lime*, and *lime-water*; in the former of which the lime, and in the latter the water, predominates. All ſaline ſubſtances unite with water, either in a ſolid cryſtallized ſtate, or in the ſtate of a ſolution; in the former caſe, the ſaline ſubſtance, and in the latter, the water, being predominant. The two modes in which vitriolic acid and mercury combine, appear in the *vitriol of mercury* and in *turbith mineral*; in the former of which compounds the acid, and in the latter, the mercury predominates. The double mode of combination frequently appears in metallic allays, in which, although the component parts are diffuſed through each other in different proportions by violent heat, yet, when they are kept long in fuſion with the leaſt requiſite heat, the precipitations and ſeparations which take place, indicate the diſpoſition to form differently proportioned compounds. Many more inſtances might be adduced to ſhew the different modes in which bodies that have a chemical affinity to each other are capable of combining: and indeed ſo many inſtances occur, that I am inclined to believe that it may be conſidered as a general rule, and a rule of the firſt importance, in the explanation of chemical phenomena.

When a greater number of elements or component parts than two unite together in the formation of a compound, they are capable of more modes of combination. Thus the number of modes in which three bodies may be combined is ſix, if every combination that is arithmetically poſſible could be formed into a chemical compound. Four elements might be combined in 24 different modes; five elements in 120 different modes, and ſo on. Now although our experience does not lead us to believe that every combination among three or more bodies, chemically related to each other, which is arithmetically poſſible, can actually take place in the forming of compounds; yet, from the analogy of the two modes of combination which two elements, thus chemically related to each other, are capable of, as we have above explained, and alſo from the inſtances that are known of the various modes of combination, in which three or more elements are formed into different compounds, we cannot doubt that the number of modes does frequently encreaſe with the number of component parts, although not in the full arithmetical extent.

How much the properties of compounds, conſiſting of the ſame component parts, are affected by the different modes of combination, that is, how different they are, is too obvious to require any proof or illuſtration.

131. We now proceed to examine the conſtitution of the ſeveral permanently elaſtic fluids deſcribed in the preceding chapters, all which may be comprehended under the following ſeven claſſes.

1. *Acid gaſes.*
2. *Alkaline gas.*
3. *Inflammable gaſes.*
4. *Calcareous gas.*
5. *Nitrous gas.*
6. *Air.*
7. *Phlogiſticated air.*

Of Acid Gaſes.

132. We have ſeen that the vitriolic, nitrous and marine acids may, when united with any inflammable matter, be converted by heat into thoſe gaſes which we have called *acid*, becauſe they ſeem to retain their acid properties, of acting upon the metallic, alkaline, and other ſubſtances, with which they combine when in a liquid ſtate; and alſo, of uniting readily with water, by which they are reduced to their original ſtate of liquid acid. As theſe fluids are not condenſable by the cold of the atmoſphere, they have been conſidered as gaſes; but from their eaſy reduction to their former concrete ſtate, and from their retain-

ing their acid properties while in their expanded ſtate, they ſeem to be of the more imperfect kind of thoſe fluids. It may be obſerved, that theſe gaſes are not formed by any violent action, inteſtine motion, or decompoſition of bodies; but that they are raiſed merely, as vapours are, by moderate heat. Do not then theſe gaſes conſiſt of acids volatilized by means of water and phlogiſton? Does not the acid part greatly predominate over the phlogiſtic in their compoſition; and is not the phlogiſton in a very imperfect ſtate of combination with the acid, becauſe this acid is united with much water, and becauſe water does not eaſily combine with phlogiſton? And do not the acid properties of theſe gaſes depend on this imperfect combination with phlogiſton, and on the predominancy of acid in their compoſition*?

Of Alkaline Gas.

133. The elaſtic vapour raiſed by heat from *volatile alkali* was found to be not condenſable by the cold of the atmoſphere; and it has been deſcribed, as the abovementioned acid vapours have, under the name of *gas*. But it may be obſerved of both acid and alkaline vapours, that if upon further examination they be found not condenſable by any cold which we can apply to them, and be therefore properly compre-

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* That the vitriolic acid gas contains the ſame elements as ſulphur does, appears from a fine experiment of Dr. *Prieſtley*, an account of which will probably be given in his fourth volume of Experiments and Obſervations, now preparing for the preſs, but which he has been pleaſed to allow me to mention here. He expoſed ſome water impregnated with vitriolic acid gas to a long-continued heat in a glaſs tube hermetically ſealed: after which, he obſerved that the inſide of the upper part of the tube was coated with white cryſtallizations, that were found upon examination to be perfect *ſulphur*. In this experiment the adheſion of the principles of the gas ſeems to have been ſo weakened by the water, that a part of them ſeparated and formed this new compound.

hended under the definition of *gas* given in chap. I. they muſt be allowed to be of the moſt imperfect kind of permanently elaſtic fluids. For neither the acid nor alkaline elaſtic fluids can be conſidered as compounds formed, during their expanſion into an elaſtic ſtate, from decompoſed and violently ſeparated parts; but as merely the disjoined parts of the bodies, from which they are raiſed, retaining, while in their elaſtic ſtate, the properties of theſe bodies; and capable of being reduced, when condenſed by water, into concretes, or bodies ſimilar to thoſe from which they were formed.

Of Inflammable Gaſes.

134. We have ſeen that *inflammable gaſes* are formed from the vitriolic or marine acids acting on iron, zinc, or tin; from marine acid gas acting upon theſe metals, or upon almoſt any inflammable ſubſtance; from many inflammable compounds, by means of heat, as from coals, vegetable and animal ſubſtances, during the decompoſition of theſe compounds; and from animal or vegetable matters undergoing the putrefactive fermentation.

In the abovementioned different kinds of inflammable gas, we may perceive that acids and inflammable matter are the principal ingredients, not only in the metallic ſolutions, in which the acid unites with the phlogiſton of the metals, but alſo in the vegetable and animal matters, by the analyſis, or by the putrefaction of which, inflammable gaſes are produced. For in theſe matters, the vegetable and animal acids abound; and from their inflammability, it appears that the acids are combined with phlogiſton. The converſion of the marine acid gas into inflammable gas, by the action of that acid fluid on phlogiſtic ſubſtances, ſufficiently ſhews that an acid enters into the compoſition of this inflammable gas. The inflammability alſo of the diſengaged gas of hepar of ſulphur can ſcarcely be ſuppoſed to ariſe from any other matter than phlogiſton and acid.

Other kinds of inflammable gas have been deſcribed, in the production of which no acid is employed; ſuch are the gaſes formed from metals merely by heat, or, by means of alkalies. Theſe inflammable gaſes ſeem to conſiſt of the ſame component parts as the metals themſelves, that is, of phlogiſton and earth in different proportions. In metals the earth predominates, but in this inflammable gas, the phlogiſton predominates. And that the phlogiſton in theſe inflammable gaſes is not pure and uncombined, may be inferred from its not being ſeized upon by the air as ſoon as they come into contact with this fluid; whereas heat, and even ignition, is neceſſary for the decompoſition of theſe, as of other inflammable compounds. Are not all the inflammable bodies that we know, whether in a concrete or expanded ſtate, compounds of phlogiſton, united either with acids, or with earths; with this difference only, that the inflammable concretes, ſuch as ſulphur, oils, bitumens, and metals, are compounds in which the acid or earth predominates over the phlogiſton, and the inflammable gaſes are compounds in which the phlogiſton predominates over the acid or earth.

We have remarked, (§. 127.) that the moſt perfect gaſes are formed by a violent ſeparation of parts. Now, in all the modes of forming inflammable gas, the ſubſtances are diſſolved or decompoſed, and their parts violently torn aſunder. The inflammability alſo of this gas is greater, when the heat is ſuddenly applied, or when the ſolution proceeds with violence.

And accordingly, the properties of this gas indicate it to be of the moſt perfect kind; for, it is the rareſt, and the moſt immiſcible with water, of any known gaſes. Theſe properties probably proceed from the phlogiſton which ſeems to abound in this gas.

Iron, zinc, and tin, are the metals from which inflammable gaſes are moſt eaſily produced: and the reaſon ſeems to be, that theſe metals, when diſſolved by acids, do moſt eaſily part with their phlogiſton, as chemiſts have often obſerved.

Of Nitrous Gas.

135. We have ſeen that inflammable gaſes have been formed by means of the vitriolic, the marine, the vegetable, and the animal acids. But no method has been yet diſcovered of making a perfect inflammable gas, by means of the nitrous acid; although we have ſeen ſome approaches towards it, §. 86.* Nevertheleſs, the *nitrous gas*, deſcribed in chap. V. ſeems to be ſomewhat analogous in its compoſition to inflammable gas. For it is formed from an acid acting upon metallic and phlogiſtic ſubſtances; and the combination of phlogiſton with the acid ſeems to be ſo intimate, that it ſuppreſſes the peculiar qualities of

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* Since the above was ſent to the preſs, Dr. *Prieſtley* has been ſo obliging as to communicate a very curious experiment which he has lately made. He put a pot containing a mixture of iron-filings and ſulphur into a jar filled with nitrous gas, and he obſerved, that after the gas had ſuffered the great diminution mentioned in §. 86. it encreaſed in bulk, and became *ſtrong inflammable gas*. It retained its properties of nitrous gas till it was diminiſhed to leſs than one third. Then it admitted a candle to burn in it with an enlarged flame; after which, it acquired the properties of *phlogiſticated air*, and laſtly it became, as we have ſaid, ſtrongly *inflammable*. Do not this, and the many other extraordinary inſtances of converſion of one gas into others, ſhew that they contain the ſame component parts differently proportioned and combined?

the acid; for this gas does not act as an acid upon metals or other ſubſtances; neither does it very readily mix with water, without the contact of air; and even when abſorbed by water, it does not communicate its acid qualities to the liquid, till the water has been expoſed to air, which decompoſes the gas, and diſengages its acid, as Mr. *Bewley* has well obſerved. The phlogiſton however, in this gas, does not ſeem to be ſo perfectly combined, as it is in the inflammable gaſes, for the following reaſons; 1. This gas is conſiderably denſer, being as heavy as common air is*; whereas inflammable gas is greatly lighter. 2. It mixes more readily with water than inflammable gas does. 3. It parts with its phlogiſton more eaſily; for, no ſooner does air come in contact with this nitrous gas, than the phlogiſton ſeems to paſs from the latter to the former; and the acid thus deprived of the ſubſtance to which it owed its elaſtic ſtate, is changed into a liquid concrete, or ſpirit of nitre. Although therefore nitrous gas cannot be inflamed, it appears to undergo a proceſs ſimilar to that of inflammation, namely, a ſeparation of its phlogiſton by means of air: and the difference ſeems to be, that the phlogiſton is ſo firmly combined in the inflammable gaſes, that it cannot be ſeparated from its acid by the ſuperior attraction of the acid of the air, till its activity has been encreaſed by ignition; whereas, it is ſo much leſs perfectly combined with the acid in the nitrous gas, that it is ſeparated immediately upon mixture with air.

From theſe reaſons, I am inclined to think that a portion of water enters into the compoſition of this gas, and prevents ſuch an intimacy of combination of

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* Experiments and Obſervations, vol. I. p. 119.

the acid with the phlogiſton, as takes place in inflammable gaſes. And that water enters into the compoſition of this gas, is further rendered probable, from the copious production of nitrous gas, when the nitrous acid vapour acts upon water. *See Chap. VIII.* §. 99.

If this conjecture be juſt, the nitrous gas ſeems to be in an intermediate ſtate between the acid and the inflammable gaſes.

Of Calcareous Gas.

136. All thoſe gaſes which occaſion a *precipitation in lime-water*, have been generally comprehended under one claſs, and diſtinguiſhed by the name of *Fixed Air*. We have ſeen that they are produced from many different materials: 1. From calcareous, and from alkaline ſubſtances, by acids, or by fire: 2. From the combuſtion of any animal or vegetable matters, or from their decompoſition by heat, or by concentrated acids: 3. From animal and vegetable matters undergoing the vinous and other fermentations: 4. From metallic calxes by reduction, and ſometimes merely by heat, as from minium: 5. From ſome metallic and other ſalts, as green vitriol, by fire: 6. From air decompoſed by electricity: 7. From the deflagration of nitre, and in the various proceſſes in which the nitrous acid is uſed to produce gaſes: 8. From ſubterranean pits and caverns: 9. From mineral waters; and probably, they may be obtained from many other ſubſtances.

Perhaps, in all theſe gaſes, the ſame mode of combination prevails, although the acids which enter into their compoſition be different. From the above enumeration of the various modes of production, almoſt any acid ſeems capable of aſſuming this ſtate. But the animal and vegetable acids appear to be peculiarly diſpoſed to form this gas. For, we find from the experiments of Dr. *Hales*, that a very large proportion of the vegetable eſſential ſalts, as tartar, were converted into a gas of this kind; when theſe ſaline ſubſtances were decompoſed by fire. In this operation, the acid diſappears, and a gas is produced. For no gas exiſts in the tartar, or other vegetable body, till it be decompoſed; the gas being a peculiar compound formed, during the decompoſition of the vegetable matters, by fire, or by fermentation. Thus when tartar is united with fixed alkali, as in making *Rochelle* ſalt, the alkali, if cauſtic, is not rendered mild; and, on the contrary, if mild, its gas will be expelled by the tartar, as it would by any other acid. But, if this compound of tartar and cauſtic alkali, in which no gas exiſts, be burnt, the alkali remaining will be mild and effervefcent; for the acid of the tartar being decompoſed by the fire, and formed into a gas, a part of it will unite with the alkaline reſiduum. And if *ſoap*, which conſiſts of cauſtic alkali and oil, be burnt, the alkali will be rendered mild, by the gas formed from the acid, which is known to be a conſtituent part of oil. Alſo, if nitre be deflagrated with any animal or vegetable matter, the alkaline baſis of the nitre, which is not united with gas while combined with the nitrous acid, will, after the deflagration, be found to be united with gas, that is, rendered mild; whereas, if nitre be deflagrated with zinc or tin, which metals contain no acid capable of converſion into gas, the alkaline reſiduum will be cauſtic †.

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† The production of a mild alkali by deflagration of nitre with charcoal, and of a cauſtic alkali by deflagration of nitre with filings of zinc, or of iron, has been alſo noticed by Mr. *Bewley*. *Appendix to Dr. Prieſtley's third vol. of Exper. and Obſerv. p.* 387.

The exiſtence of an acid, as a principal conſtituent, and even as the predominant part of this gas, is indicated by ſeveral of its properties. For it acts upon, and diſſolves ſeveral earthy and metallic ſubſtances; it unites with alkalies and calcareous earths, and it effects their cryſtallization, as other acids do; it may be diſengaged from theſe alkaline ſubſtances by ſtronger acids; it has been found to change the blue colour of the juices of turnſole, of litmus, and of cyanus, to red [*]; and it gives an acid taſte to the water which it impregnates.

The acid quality, however, of this gas, is very weak, being probably counteracted by the other principles, as earth, or phlogiſton, which in many inſtances are known to leſſen or deſtroy the activity of acids [†].

Of Air.

137. Of all the gaſes, *air* being of the greateſt importance to us, has been moſt attentively examined by philoſophers; a knowledge, however, of its conſtitution, and of the mode of operation, by which its ſingular effects are produced, has nevertheleſs eluded their inquiries. The exiſtence of an acid, and even of the nitrous acid in air, has indeed been ſuſpected, chiefly, from the neceſſity of air towards the formation of nitre,

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[*] Dr. *Prieſtley*'s Exper. and Obſ. vol. I. 31. and Appendix to vol. II. by Mr. *Bewley*.

[†] Signor *Fontana*, in a treatiſe entitled, *Ricerche Fiſiche ſopra l'Aria fiſſa*, attributes the acidity of the gas extracted from calcareous ſubſtances by means of oil of vitriol, to the acid employed, which he thinks may be diſſolved in this gas, as water is diſſolved in air, ſo intimately, that neither water nor alkali can ſeparate this acid; and he thinks, that to this volatilized and combined vitriolic acid, the fixed air owes its medicinal qualities, the acid being thus rendered more efficacious than in its proper uncombined ſtate. And alſo Signor *Landriani*, in his *Ricerche Fiſiche interno alle ſalabrito*

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and from the analogous effects of nitre, and of air, in promoting inflammation. But, no experiments have been ever adduced to give ſuch ſolidity to this conjecture, as thoſe of Dr. *Prieſtley*, which ſhew that a fluid reſembling air in all its known properties, and even poſſeſſing the peculiar properties of air in a much more eminent degree than the atmoſpherical air itſelf does, may be produced from nitrous acid mixed with almoſt any unphlogiſticated earth.

Nevertheleſs we cannot, with certainty, infer, that the nitrous is the ſole acid capable of forming fluids poſſeſſed of the properties of air, and conſequently that the atmoſpherical fluid does certainly contain in its compoſition ſome of that acid. For a very ſtrong reſemblance, between two compounds, may ariſe from the ſimilarity of the combination, although a component part of one compound may be of a different ſpecies from the analogous component part in the other compound. Thus we have ſeen, that inflammable gaſes ſimilar in their properties, ſo far as we have examined them, are formed from very different acids, the vitriolic, marine, and others; and we have alſo ſeen, that thoſe gaſes, which, from their ſimilarity of properties, have been conſidered as being of the

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dell' Aria, maintains, that the acidity of this gas proceeds from the acid employed in the operation of extricating it, and that when this gas is mixed with vapour or volatile alkali, an ammoniacal ſalt will be formed, which will be found to be a vitriolic ammoniac, if the acid employed had been the vitriolic, and a deflagrating nitrous ammoniac, if nitrous acid had been employed. Mr. *Bewley*, in the Appendix to Dr. *Prieſtley*'s ſecond volume of Experiments and Obſervations, very well defends the opinion of the intrinſic acidity of this gas, and ſhews that the ſame indications of acidity are exhibited by gaſes extricated from volatile alkali and from magneſia, by heat, and without intervention of any foreign acid.

the ſame kind, and comprehended under the ſame name, *fixed air*, or *calcareous gas*, are ſimilar compounds, formed from very different ſubſtances, and probably containing in their compoſition very different acids. Theſe conſiderations prevented me, in the firſt Edition of this Treatiſe, from admitting the certainty of the nitrous acid being a neceſſary conſtituent part of the atmoſpherical fluid, although it was allowed that the production of one ſpecies of factitious air, by means of that acid, with various unphlogiſticated earths, was completely aſcertained by Dr. *Prieſtley*'s experiments. The recent experiments that have been ſince made, and related in §. 31. ſhew that a pure air may be obtained by means alſo of the *vitriolic acid*, and ſeem to leave no doubt, that fluids, poſſeſſing all the known properties of the atmoſpherical fluid, may be produced from more than one acid, and from various kinds of earths*.

Whether the earths employed in the proceſſes for making factitious airs enter into the compoſition of air, and in what proportion, are queſtions which cannot be aſcertained by the experiments hitherto made †.

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* An experiment is related by Mr. *Macquer*, which ſeems to ſhew that the *marine acid* is poſſeſſed of that very property which has been thought peculiar to nitrous acid and to air, and from which the analogy of theſe two ſubſtances has been chiefly deduced; namely, the property of maintaining combuſtion. "I introduced "(ſays that author) a lighted taper into a receiver filled with "vapours of highly-concentrated marine acid, through a tubu-"lated aperture. The flame of this taper, which was, before con-"tracted, white and almoſt without ſmoke, now became long, "pointed, yellow, and ſmoking, like the flame of burning tur-"pentine. But the moſt remarkable circumſtance was, that the "flame ſubſiſted a *much longer time*, than when the taper was in-"troduced into the ſame receiver filled with pure air."

† Dr. *Prieſtley* has made ſome experiments to aſcertain the proportion

If theſe earths are capable of being converted into elaſtic fluids, the reſiſtance they make to this change renders it probable, that the fluids thus formed will be of the moſt perfect kind, and of the moſt permanent elaſticity. *See* §. 127. The diſpoſition which earths have to unite with phlogiſton has been already noticed: but this tendency may exert itſelf much more powerfully, when it is not counteracted by the mutual coheſion of the particles to each other, by theſe being reduced to a fluid ſtate. Hence perhaps the ſingular avidity with which air ſeizes upon phlogiſton in combuſtion, reſpiration,

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portion of nitrous acid, and of earth contained in the factitious air made from ſpirit of nitre and earth; but he does not conſider them to be deciſive. The queſtion is important, but ſeems difficult of ſolution. The *Abbe Fontana* maintains, that this factitious air conſiſts of ſpirit of nitre only, without earth or phlogiſton; and he ſupports his opinion by the following experiments: He converted a given quantity of mercury into red precipitate; and he expelled from this preparation as much air as he could. Then he revived the mercury of the remaining precipitate, and found that the quantity obtained was equal to the quantity of mercury originally employed. Dr. *Prieſtley* has repeated the experiment; and found that there was a loſs of about one eleventh part of the employed mercury: and Mr. *Magellan*, repeating the ſame experiment, loſt about one third of the mercury. It appears then there muſt have been ſome error in the *Abbe*'s experiments; but the experiments of Dr. *Prieſtley*, and of Mr. *Magellan*, are not applied by theſe gentlemen to aſcertain the quantity of earth actually converted into air: neither do I think that they *prove*, that any earth enters into the compoſition of the air; for in all the productions of air by heat, from earthy ſubſtances, the riſing air elevates a great deal of earth, and this earth renders the air turbid, gives the appearance of white clouds, and at laſt ſubſides. Dr. *Prieſtley* obſerves, that the air is tranſparent while hot, and becomes turbid when cold; which ſhews that ſome earth is diſſolved in the air, and that cold air not being able to keep diſſolved ſo much earth as hot air, part of the earth that was diſſolved while the air was hot, is precipitated by cold.

ration, mixture with nitrous gas, and in all the various phlogiſtic proceſſes, might be attributed to the earthy part which is ſuppoſed to enter into the compoſition of air, if the ſtriking analogy between the effects of air and of nitrous acid, in ſeveral of theſe inſtances, and alſo the ready converſion of nitrous acid into factitious air, did not give a greater degree of probability to the opinion, that an acid is the predominant principle in the compoſition of this fluid. Perhaps acids, while they are converted into air, ſuffer ſuch a change or decompoſition, as to be deprived of the ſpecific properties which diſtinguiſh the ſeveral kinds of acids from each other, while they retain only the general character of acid; and thus the ſame compound may be produced from different acids. But of all the acids, the *nitrous* ſeems to be the moſt eaſily convertible to the ſtate of air*.

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* The opinions which I have here maintained, that moſt of the known gaſes conſiſt principally of acid and phlogiſton; that the fluid called *calcareous gas*, or *fixed air*, is of an *acid* nature; and that the *nitrous* and *vegetable acids* are convertible into permanently elaſtic fluids, were ſuggeſted in the notes which I added to the firſt *Engliſh* edition of the *Dictionary of Chemiſtry*, publiſhed in 1771. Thus at the article *Fixable Air* are the following paſſages: "Have not the fluids, ſeparable from alkaline and metallic ſubſtances, ſome analogy with *acids?* Like acids, they readily "*unite* with, and effect the *cryſtallization* of thoſe (alkaline) ſubſtances. As a *weaker* acid is extricated from thoſe ſubſtances "by a *ſtronger*, ſo is this (fixable) air by all known acids. Are "not the elaſtic fluids produced by the *deflagration of nitre*; and "by the *combuſtion* or *alkalization* of *tartar*, and of other *vegetable acid ſalts*, formed from the *acids* of theſe ſubſtances combined with the *inflammable principle?*"——"A permanently "elaſtic fluid or fixable air is produced by *deflagration* of *nitrous acid* with any inflammable ſubſtance. In this operation the acid "diſappears, and an elaſtic vapour is produced. May we not "thence

138. However imperfect our knowledge of the conſtitution of the atmoſphere may ſeem, the explanation of the ſingular properties of the air in maintaining fire and the reſpiration of animals, in diminiſhing nitrous gas, in calcining metals, and in being diminiſhed by the various means already deſcribed, will be attended with no leſs difficulty and obſcurity. The way to truth, however, muſt be felt for, when it cannot be ſeen; and, accordingly, we proceed in our conjectures.

We may perceive, that almoſt all the chemical changes which happen to bodies, are the reſult of decompoſitions, occaſioned chiefly by the application of ſubſtances, whoſe attraction to ſome of the parts of theſe bodies is ſtronger than the attraction of the parts to each other. This general obſervation has been applied to explain the effects of air. It has been ſuppoſed that air, or its acid, have a ſtronger attraction to phlogiſton than any other ſubſtance; and conſequently,

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"thence infer, that the *acid* is *converted* by combination with "ſome other ſubſtance, probably with the *inflammable matter*, or "by decompoſition of its own ſubſtance, into elaſtic vapour?" *Vol. I. p.* 36. And in a note to the article *Mineral Waters*, it is ſaid; "Does not the *ſolution of calcareous earths*, by fixable air, "confirm a conjecture concerning the analogy of this vapour with "acids?" *Vol. II. p.* 838. Since the publication of that work, this opinion has been further confirmed by many of the new facts which have been diſcovered; and the acid quality of the gas, called *Fixed Air*, has been noticed by other later writers. Thus M. *Bergman*, as Dr. *Prieſtley* informs us, (*Exper. and Obſervat. vol. I. p.* 31.) is induced, from the effects of this gas on the colour of vegetable flowers, to conſider it as an acid, and to call it the *Aerial Acid*. And Mr. *William Bewley* has added an Appendix to Dr. *Prieſtley*'s ſecond volume, entitled, "Experiments and Ob"ſervations, tending to prove that Fixed Air is the Vapour of a "*particular* Acid." Mr. *Bewley* diſtinguiſhes this fluid by the name of *Mephitic Acid*.

ſequently, that, where any inflammable ignited body is expoſed to air, the phlogiſton leaves this body, and unites with the air.

The *deflagration of nitre* is alſo explained, by ſuppoſing that the nitrous acid poſſeſſes an attraction to the phlogiſton of the inflammable body employed, ſuperior to the attraction of the parts of that body. And the *detonation of fulminating gaſes* ſeems to proceed from the ſudden converſion of acid, together probably with ſome phlogiſton, into gas, as has been already ſuggeſted, §. 123.

The *calcination of metals* is conſidered by chemiſts as a ſlow combuſtion; and the air is ſuppoſed to operate in the ſame manner as in other combuſtions.

139. Various opinions have been formed concerning the mode of operation by which the *reſpiration of air* is neceſſary to the life of breathing animals. See *Haller's Phyſiology*, and *Experiments and Obſervations, vol. III. p. 55.* Of theſe opinions, that which ſeems moſt probable is given by Dr. *Prieſtley*, namely, that reſpiration is a true phlogiſtic proceſs, in which the phlogiſton, with which the animal ſyſtem abounds, is diſcharged from the blood by the lungs, and combined with the reſpired air. And accordingly, the air which has been reſpired, is found to have ſuffered the ſame changes which it does in other phlogiſtic proceſſes, that is, its bulk is diminiſhed, it extinguiſhes flame, and it occaſions a precipitation in lime-water, which ſhews that it contains ſome portion of calcareous gas. He further confirms this opinion, by the remarkable changes which blood undergoes by expoſure to air. Mr. *Hewſon* had diſcovered that blood received a florid colour from air during its paſſage through the lungs. See *Mr. Hewſon's Experimental Inquiry*

Inquiry into the Properties of Blood. M. *Cygna* had alſo ſhewn, that a florid colour could be given to the under black part of the coagulum of blood, by expoſing this part to air; and that the upper ſurface of blood was black in vacuo. *Miſcell. Taurin. I.* 73. To theſe obſervations Dr. *Prieſtley* has added others equally important. He found that the change produced by air on the colour of blood, was not prevented by the interpoſition of a bladder, nor of the ſerum of blood; that blood was rendered florid in a more remarkable degree, by pure factitious air; that blood was rendered black by inflammable, nitrous, and calcareous gaſes, and alſo by phlogiſticated air; that by expoſing blood to air, this fluid was thereby phlogiſticated; and that by expoſing blood to the other gaſes, theſe ſuffered conſiderable changes, the bulk of the *nitrous gas* being thereby leſſened, and its property of being condenſed by mixture with air being conſiderably diminiſhed; the *inflammable gas* being thereby made to approach ſo far to the ſtate of air, as to be capable of effecting a conſiderable diminution of nitrous gas; and *phlogiſticated air* being alſo rendered capable of producing ſome diminution of nitrous gas. *See Exper. and Obſerv. vol. III. p.* 55, *&c.*

140. Dr. *Prieſtley* alſo conſiders the effects of *mixing nitrous gas with air* as a phlogiſtic proceſs, in which the air deprives the gas of its phlogiſton; and he ſuppoſes, that, in all thoſe inſtances where air is diminiſhed by liver of ſulphur and other phlogiſtic ſubſtances, the air attracts and combines with the phlogiſton of theſe ſubſtances, and becomes thereby *phlogiſticated.*

If it ſhould be aſked why the phlogiſton of inflammable bodies cannot be ſeparated without heat, and even ignition; whereas this phlogiſton may be ſeparated from nitrous gas, from the blood in reſpiration, from liver of ſulphur, and other phlogiſtic bodies, merely by contact of air; may we not anſwer, that, in the latter inſtances, the phlogiſton is but ſlightly attached, and eaſily ſeparated; whereas, in inflammable bodies, it is ſo intimately combined, that it cannot be ſeparated, till the parts of theſe bodies have been thrown into violent agitation by heat, their cohesion diminiſhed, the volatility and activity of the phlogiſton encreaſed, and its combination with air thus facilitated? And may not the intenſe heat, flame, and other effects of burning bodies, proceed from the agitation excited among their moſt active parts, from the violence with which they are torn aſunder from each other, and from the rapidity with which the minute and elaſtic particles of air and phlogiſton ruſh into union? For, in what does *heat* conſiſt, but in the exceedingly quick vibrations of the particles of burning bodies; or *light*, but in the extreme rapidity and force with which the moſt active particles are thrown from the ſurfaces of theſe bodies?

If it ſhould be aſked why air, or, at leaſt, why the factitious air, which is produced from nitrous acid, ſhould take phlogiſton from nitrous gas, which is alſo formed principally from that acid; may we not anſwer, that, although each of theſe fluids contain, in their compoſition, nitrous acid, yet they are very different combinations? For, if the nitrous gas contain, as has been above conjectured, a conſiderable portion of water in its compoſition, its attraction to phlogiſton will be thereby ſo weakened, that air may be able to deprive it of this eſſential part to its elaſtic ſtate; while the other parts in the compoſition of this nitrous gas, the acid and the water, ſhall be condenſed and reduced to the ſtate of liquid nitrous acid.

M. *Lavoiſier* is of opinion, that nitrous acid is not a conſtituent part of air, but that air is a conſtituent part of nitrous acid, and that the nitrous acid, formed upon mixing nitrous gas with air, is compoſed of both theſe fluids united together, and therefore that the nitrous gas does not contain the nitrous acid, but only a ſubſtance proper to form it, by combining with air.

Whence proceeds the heat that is obſerved upon the mixture of nitrous gas with air? May it not be a neceſſary conſequence of the condenſation which inſtantly happens upon the mixture of theſe two fluids? For, is it not an univerſal rule, that cold is produced by the expanſion of bodies into a rarer ſtate; and heat by their condenſation? Hence the cold produced during the evaporation of fluids, and during the rarefaction of air, by means of the air-pump; and hence the heat which is communicated by vapours during their condenſation, which has been obſerved to be much greater than can be communicated by an equal quantity of any concrete matter heated to the ſame temperature.

Hence alſo the heat that is obſerved to accompany *fogs*, which are nothing but condenſed vapours. Are not the other diminutions of air, and condenſations of elaſtic fluids, alſo accompanied with heat *?

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* Heat is generally produced, while two ſubſtances combine, and their combination is accompanied with condenſation; that is, when the new compound occupies leſs ſpace than its conſtituent parts did before their union. But the combination of phlogiſton with air is always accompanied with condenſation, as appears from the diminution of the air in all phlogiſtic proceſſes. May not then the heat produced by the union of air with phlogiſton in the lungs of animals, during their reſpiration, be one cauſe of *animal heat*?

141. The *alteration produced in air*, by the *phlogiſtic proceſſes*, is very remarkable. Air, by this phlogiſtication, ſeems to be converted into two diſtinct compounds, *phlogiſticated air*, and *calcareous gas*, both which are very different in their properties from air. While the phlogiſton unites with that part of air to which it ſeems to be moſt diſpoſed, and forms with it the new compound *phlogiſticated air*; the other parts of air, leſs diſpoſed to unite with phlogiſton, are precipitated, forming another compound, which, from its property of occaſioning a precipitation in lime-water, appears to be the fluid deſcribed under the name of *calcareous gas*. We might ſuſpect that this gas proceeded from the burning body, or ſubſtances, on which the air exerts its action, if we did not know that the ſame gas was produced when air is decompoſed by electrical ſparks paſſing through it.

Whether this gas be precipitated from air; or be a compound formed from the decompoſed parts of the burning ſubſtance; or, laſtly, whether ſome gas of this kind may not proceed from both theſe cauſes; we nevertheleſs can ſcarcely doubt that ſome part of the air is ſeparated, fixed and combined with the burning ſubſtance. This opinion is confirmed by the following experiment of M. *Lavoiſier*.

He burnt ſome phoſphorus under a bell, the inner ſurface of which was moiſtened with diſtilled water. The quantity of phoſphorus employed was 186 grains. Of this quantity thirty-two grains remained unconſumed; and therefore 154 grains were actually burnt. The vapours of the phoſphoric acid being condenſed by means of the water, with which the bell was moiſtened, were collected and weighed in a narrow-necked veſſel; by which means he found, that the weight of the acid liquor exceeded the weight of an equal bulk of diſtilled water 243½ grains, which was 89½ grains more than the quantity of phoſphorus conſumed. Theſe 89½ grains could not be water attracted by the phoſphoric acid, for the ſpecific gravity of the liquor could not have been thereby encreaſed; and he therefore infers, that this acceſſion of matter muſt have proceeded from ſome part of the air abſorbed during the combuſtion.

In one inſtance however of air being diminiſhed, no calcareous gas is precipitated, namely, the calcination of metals, which is conſidered as a combuſtion. Dr. *Prieſtley* alledges ingeniouſly, that the gas is formed in this as in other inſtances, but is abſorbed by the calcining metal, and that this is the part of air, by the abſorption of which, metals acquire weight during their calcination. This abſorption of gas would be rendered more probable, by the conſideration that, during the reduction of metallic calxes, a quantity of this calcareous gas is obtained, if the addition of inflammable matter neceſſary for ſuch reduction did not leave ſome ſuſpicion, that this matter might poſſibly furniſh the gas thus produced.

142. The weight gained by metals during their calcination, is a fact too extraordinary not to have employed the ingenuity of philoſophers in explaining its cauſe. *Boyle* and *Lemery* have attributed this encreaſe of weight to the particles of *fire* or *flame*, which they ſuppoſed were abſorbed by metals during their calcination. *Charas*, a chemiſt cotemporary with *Lemery*, aſcribes this effect to the *acid* of the *wood*, or of the *coal* employed in the calcination.

M. *Venel* and M. *Morveau* maintain, that this encreaſe of weight is not occaſioned by the addition of any ſubſtance to the metallic matter, but by *depriving* this matter of its *phlogiſton*. For theſe philoſophers pretend, that phlogiſton is endowed with a power contrary to that of gravitation, namely, of receding from the center of the earth, and thereby of rendering bodies, of which it makes a part, lighter than they otherwiſe would be. It is evident that a doctrine attributing to this phlogiſton (a ſubſtance which is not the object of any of our ſenſes) a property directly contrary to *gravitation*, which is an undoubted property of all thoſe ſubſtances that are the objects of our ſenſes, requires to be ſupported by very deciſive experiments, and unequivocal arguments.

As the air is diminiſhed by the calcination of metals, while theſe, at the ſame time, gain an acceſſion of weight, we cannot heſitate to aſcribe this acceſſion to the abſorption of air, or of ſome part of it, as has been already obſerved. *See* §. 13. *and note ſubjoined.*

Some inſtances have been mentioned (§. 26.) of metallic calxes yielding pure air by means of heat. That this pure air has been abſorbed from the atmoſphere, ſeems highly probable; and as the preparation of minium and of calcined mercury, requires a longer expoſure to the action of fire and of air, than that of other calxes, theſe metallic matters may perhaps be deprived more perfectly of ſuperabundant phlogiſton, or may abſorb a larger quantity of air than the calxes of other metals. Neverthelefs, we can ſcarcely conſider the pure air thus abſorbed by minium and calcined mercury as the ſubſtance eſſential to them as calxes, and to which their additional weight is principally owing; for minium, after it has been deprived by heat of all its pure air, ſtill retains its calciform ſtate, and is heavier than the lead from which it was produced *.

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* The calx of mercury may indeed be revived or reduced by the heat of a furnace in cloſe glaſs veſſels without any addition of inflammable matter. And thus the ſame operation ſeems to effect the reduction of this calx, and the expulſion of air from it; which would ſeem to ſhew that its calciform ſtate is occaſioned merely by the preſence of this air; and accordingly Mr. *Bayen* has inferred from

143. Are not *metallic precipitates*, combinations of acid and metallic earth? And is not the revival of theſe precipitates effected by the combination of phlogiſton with the adhering acid, forming a gas; and with the metallic earth, forming the revived metal?

144. The production of air, by water decompoſing or abſorbing part of the calcareous and other gaſes, §. 25; the precipitation of calcareous gas from air, by the ſeveral phlogiſtic proceſſes; and the ſeveral inſtances above mentioned of nitrous, inflammable, and other gaſes being ſo altered by various ſubſtances, as to loſe their ſpecific characters, and to approach to that of air; ſeem to ſhew that theſe fluids contain in their compoſition the ſame elements, and that their differences ariſe principally from the different proportions of theſe elements, which take place in different modes of combination.

145. We may eaſily perceive that many important queſtions remain to be aſcertained on the ſubject of this Treatiſe: And although we are highly indebted to the ſagacity and induſtry of thoſe philoſophers who have led us to our preſent ſtate of knowledge, yet much more remains undiſcovered to excite and recompenſe the zeal of future labourers in this fertile and ſtill new field of ſcience.

When we ſhall be able more fully to aſcertain the con-

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from this fact, that calxes may be revived without addition of phlogiſton, and that the theory of *Stahl*, which makes the calcination of metals to conſiſt in the depriving them of phlogiſton, is thereby overthrown, But a concluſion from a ſingle fact, ſubverſive of a theory founded on the general courſe of appearances, ought to be very cautiouſly admitted. For it may be doubted, whether the very ſmall quantity of phlogiſton, that may be neceſſary to the revival of the calx of mercury, may not paſs through glaſs veſſels ſoftened by heat. Although mercury may not be capable of ſo perfect a calcination as the imperfect metals, nevertheleſs it is ſo far changed by the combined action of air and fire, as to loſe not only its metallic appearance, but alſo, like other volatile metallic ſubſtances, to be rendered conſiderably more fixed when expoſed to heat. It is even ſaid to ſuſtain a *fuſion* or *vitrification*, like other metallic calxes, when expoſed to the pure heat of a burning glaſs. *See a note of Dr. Lewis, in his tranſlation of Newman's Chemiſtry, vol. I. p.* 134.

conſtituent parts of the ſeveral gaſes, the proportions of theſe parts to each other, and the circumſtances neceſſary to each mode of combination; we may then perhaps be enabled to diſcover the various compoſitions, decompoſitions and changes, which theſe fluids ſuffer in many natural operations. We may alſo perhaps be enabled to trace the ſame ſubſtance through a great variety of forms. Thus we may obſerve the oily concrete acid of vegetables undergoing its various changes through the different periods of vegetable life from ſeed to maturity; till, by the vinous or other fermentations, or by fire, it be diſengaged from the more fixed earthy matters, which were united with it, be more perfectly combined with phlogiſton, and aſſume an elaſtic ſtate. In this ſtate, it may mix with the atmoſphere, and conduce perhaps to ſome of the ſtriking phenomena which happen there; or, be abſorbed by the humid vapours floating in the air, and again conveyed by theſe vapours into the organs of vegetables: thus paſſing along in that perpetual circulation of matter, which makes the Proteus-like face of Nature, an ever-varying, pleaſing picture. Or, if we may be indulged a bolder imagination, where our yet infant experience cannot reach; may not theſe fluids, while raiſed into their elaſtic ſtate, undergo further changes? May they not be decompoſed and rarefied into the moſt active elements, and while they advance in this progreſſion of ſubtilization, may they not acquire new properties and powers, unknown in denſe matter? May they not then pervade all bodies, and become that highly elaſtic *ethereal medium*, which, as *Sir Iſaac Newton* † conjectures, may be the proximate cauſe of *coheſion*; of *gravitation*; of *electrical attraction* and *repulſion*; of the *refraction*, *reflection*, *inflexion*, and the *heat* of the *rays* of *light*; of *animal motion*, and of *animal ſenſation*?

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† *Optics*, *Quer.* 19, 20, 21, 22, 23, 24, and *Principia Mathem.* §. *ultim.*

THE END.

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